Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

25

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY—BULLETIN No. 69.
L. O. HOWARD, Entomologist and Chief of Bureau.

THE CHINCH BUG.

BY

F. M. WEBSTER,
In Charge of Cereal and Forage-Plant Insect Investigations.

ISSUED JUNE 21, 1907.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1907.

BUREAU OF ENTOMOLOGY.

L. O. Howard, *Entomologist and Chief of Bureau.*
C. L. Marlatt, *Entomologist and Acting Chief in absence of Chief.*
R. S. Clifton, *Chief Clerk.*

F. H. Chittenden, *in charge of breeding experiments.*
A. D. Hopkins, *in charge of forest insect investigations.*
W. D. Hunter, *in charge of cotton boll weevil investigations.*
A. L. Quaintance, *in charge of deciduous-fruit insect investigations.*
E. F. Phillips, *in charge of apiculture.*
D. M. Rogers, *in charge of gipsy and brown-tail moth work.*
A. W. Morrill, *engaged in white fly investigations.*
E. S. G. Titus, *in charge of gipsy moth laboratory.*
C. J. Gilliss, *engaged in silk investigations.*
R. P. Currie, *assistant in charge of editorial work.*
Mabel Colcord, *librarian.*

Cereal and Forage-Plant Insect Investigations.

F. M. Webster, *in charge.*
G. I. Reeves, W. J. Phillips, C. N. Ainslie, *special field agents.*

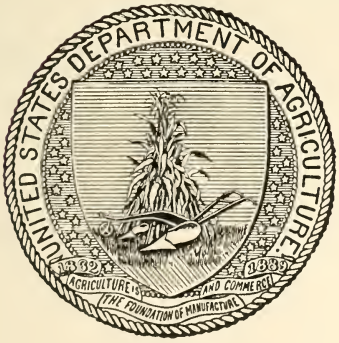
U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY—BULLETIN No. 69.
L. O. HOWARD, Entomologist and Chief of Bureau.

THE CHINCH BUG.

BY

F. M. WEBSTER,
In Charge of Cereal and Forage-Plant Insect Investigations.

ISSUED JUNE 21, 1907.



WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1907.

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Entomology,
Washington, D. C., March 5, 1907.

Sir: I have the honor to transmit for publication the accompanying manuscript entitled "The Chinch Bug," by F. M. Webster, in charge of the cereal and forage-plant insect investigations of this Bureau. This is a thorough revision by Mr. Webster of his earlier account of this destructive pest published in 1898 as Bulletin No. 15, new series, of this office, and includes additional data based on observations made during the past eight or nine years. I recommend that it be published as Bulletin No. 69 of the Bureau of Entomology.

Respectfully,

L. O. Howard,
Entomologist and Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

CONTENTS.

	Page.
Distribution	9
Hibernation	10
Spring, summer, and autumn migrations	18
Oviposition	20
Egg period and number of eggs deposited by each female	20
Descriptions of the different stages of development	21
Development and habits of the young	22
Number of generations annually	25
Destructiveness largely due to gregarious habits	28
Food plants	29
Insects that are mistaken for chinch bugs	31
Losses caused by chinch bugs	33
Natural checks	36
Influence of precipitation on the chinch bug	36
Influence of temperature on the chinch bug	43
Natural enemies	44
Parasitic fungi	44
Fungous enemies of the chinch bug determined	46
Field and laboratory experiments in Indiana	47
First field applications of fungous enemies of the chinch bug	51
The work of Professor Snow in Kansas	51
Other insects attacked by *Sporotrichum globuliferum*	53
First artificial cultivations of *Sporotrichum globuliferum*	54
Results of field applications in Ohio	54
Meteorological influences favoring development of fungous enemies of the chinch bug	56
A bacterial enemy of the chinch bug	57
The practical utility of fungous and bacterial enemies in fighting the chinch bug	58
The bobwhite or quail	58
Other bird enemies of the chinch bug	59
The frog	59
Invertebrate enemies of the chinch bug	60
Remedial and preventive measures	60
Destruction of chinch bugs while in hibernation	61
Sowing decoy plats of attractive grains or grasses in early spring	62
Difficulty of reaching chinch bugs in meadows	62
Watchfulness necessary during protracted periods of drought	63
Utility of kerosene in fighting chinch bugs	64
Utility of deeply plowed furrows supplemented by the use of kerosene emulsion	65
The surface and coal-tar method	65

Remedial and preventive measures—Continued. Page.
The ridge and coal-tar method 66
Other barrier methods 68
Necessity for preventing chinch bugs from becoming established in fields of wheat and grass 69
Summary of remedial and preventive measures 72
Probable origin and diffusion of the chinch bug 72
Indications of a probable distant origin and later diffusion 74
Unique appearance and gregarious habit 74
Occurrence of the long and short winged forms and their distribution 75
Relation of the inland and seacoast short-winged forms 78
Probable course of diffusion 78
Habits of the European species, *Blissus doriæ* Ferr 83
Previous ideas on the diffusion of the chinch bug 87
Reasons for the present theory of diffusion 88
Index 91

ILLUSTRATIONS.

Page.

FIG. 1.—Map of North America showing areas infested by the chinch bug 11
2.—Immature stages of the chinch bug 21
3.—*Blissus leucopterus:* adult of long-winged form 22
4.—*Blissus leucopterus:* adults of short-winged form 23
5.—Corn plant infested with chinch bugs 30
6.—*Nysius angustatus* 31
7.—*Piesma cinerea* 32
8.—*Corimelæna pulicaria* 33
9.—*Brachyrhynchus granulatus:* larva, pupa, and adults 33
10.—Map showing areas in the United States over which the chinch bug occurs in greatest abundance and may at any time become destructive 35
11.—Map showing distribution of the chinch bug in Ohio in 1896 37
12.—Map showing distribution of the chinch bug in Ohio in 1897 38
13.—Map showing distribution of the chinch bug in Ohio in 1894 39
14.—Map showing distribution of the chinch bug in Ohio in 1895 and amount of precipitation over the State during May, 1895 40
15.—*Triphleps insidiosus* 60
16.—*Milyas cinctus* 60
17.—Map showing probable course of diffusion of the chinch bug over North America 79
18.—*Blissus doriæ:* immature stages 83
19.—*Blissus doriæ:* adults 84

THE CHINCH BUG.

Few insects, and certainly no other species of the natural order to which this one belongs, have caused such enormous pecuniary losses as has the chinch bug, *Blissus leucopterus* Say. No other insect native to the Western Hemisphere has spread its devastating hordes over a wider area of country with more fatal effects to the staple grains of North America than has this one. But for the extreme susceptibility of the very young to destruction by drenching rains and to the less though not insignificant destructiveness during rainy seasons of the parasitic fungus, *Sporotrichum globuliferum* Speg., on both the adults and young, the practice of raising grain year after year on the same areas, as followed in the United States, would become altogether unprofitable. Some of this insect's own habits, emphasizing as they do the effects of meteorological conditions, are the most potent influences that serve to hold it within bounds, by giving its tendency to excessive increase a decidedly spasmodic character.

DISTRIBUTION.

The genus Blissus is widely distributed over the world, occurring in South Africa, Abyssinia, Algeria, Sicilia, southern Europe, northward at least to the sand dunes of central and northern Hungary, India, Japan, southern Russia, and in the Western Hemisphere in Buenos Aires, and from Panama and the Island of St. Vincent northward to middle California on the Pacific coast and Cape Breton on the Atlantic. When we come to understand that the Hemiptera of the world are far from being well known, and the faunas of South America and central Africa have as yet been hardly studied at all, we may well presume that future studies of the hemipterous insects of these countries may unite some of the different areas now known to be inhabited by the several species of this genus.

At present in the Old World this genus may be said to occur in the Ethiopian, Oriental, and Palæarctic life regions; while in the New World it ranges from the Neotropical region at Panama and St. Vincent into the Nearctic over the borders of the Boreal subregion in British America.

Our American species, *Blissus leucopterus* Say, the only one of the genus at present known in the Western Hemisphere, has been recorded from St. Vincent and Grenada, West Indies, by Uhler; Cuba, by Stål;

Volcan de Chiriqui, Bugaba, and San Feliz, Panama, by Champion; San Geronimo, Paso Antonio, Panzos, Champerico, and Rio Naranjo, Guatemala, by Champion; Lower Purissima, Lower California, by Uhler; Alameda, Cal., by Koebele; and in the vicinity of San Francisco, Cal., by both Uhler and Koebele; Orizaba, Mexico, by H. H. Smith; Tamaulipas, Mexico, by Uhler; Mesilla Park, N. Mex., by Cockerell; Florida, by Schwarz and Dr. J. C. Neal; Sydney, Cape Breton, by W. H. Harrington; Muskoka, Ontario, Canada, by E. P. Van Duzee, and Winnipeg, Manitoba, where a single specimen was collected by Dr. James Fletcher and given by him to Mr. Harrington, to whom I am indebted for information regarding its occurrence. Inland, in the United States, it may be said to be generally distributed from Texas to Manitoba. It is also very probable that its occurrence along the Pacific coast is much more extended than is at present known, as it has not been searched for to any extent in that region. (See map, fig. 1.)

HIBERNATION.

The chinch bug hibernates in the adult stage, and though there may be occasional exceptions, especially in the South, it has yet to be observed in very early spring in any other than the adult stage, at least in any locality north of Mexico. The writer observed pupæ in central Illinois apparently in hibernation in company with adults on November 11, but there is no proof that these survived the succeeding winter. In Tensas Parish, La., adults were abroad in considerable numbers during March, 1887, yet there was no indication of any young having wintered over. The adults were pairing and seemingly engaged in oviposition, precisely as is to be observed in the Northern States during May and June. No young were observed, as most certainly would have been the case had they occurred there, for observations were made in fields of young corn, where, had the young bugs been present even in very limited numbers, they would certainly not have escaped the rigid searching under and about the bases of the leaves of the young corn plants.

Doctor Howard[a] quotes Prof. G. F. Atkinson, at that time of Chapel Hill, N. C., as having observed half-grown chinch bugs on crab grass, about the 1st of October. The same authority also quotes Doctor Riley to the effect that many of the chinch bugs pair in the fall preparatory to seeking winter quarters, and also cites the fact that Mr. James O. Alwood observed them pairing in a field of uncut pearl millet, October 27, 1887, on the grounds of the Ohio Agricultural Experiment Station, then at Columbus, Ohio. Dr. Cyrus Thomas,[b] in speaking

[a] The Chinch Bug, by L. O. Howard; Report of the Commissioner of Agriculture for the year 1887, pp. 51–88.

[b] Bulletin No. 5, U. S. Entomological Commission, p. 13.

of the possibilities of an occasional third brood in southern Illinois and Kentucky, states that there were some evidences of this, but not

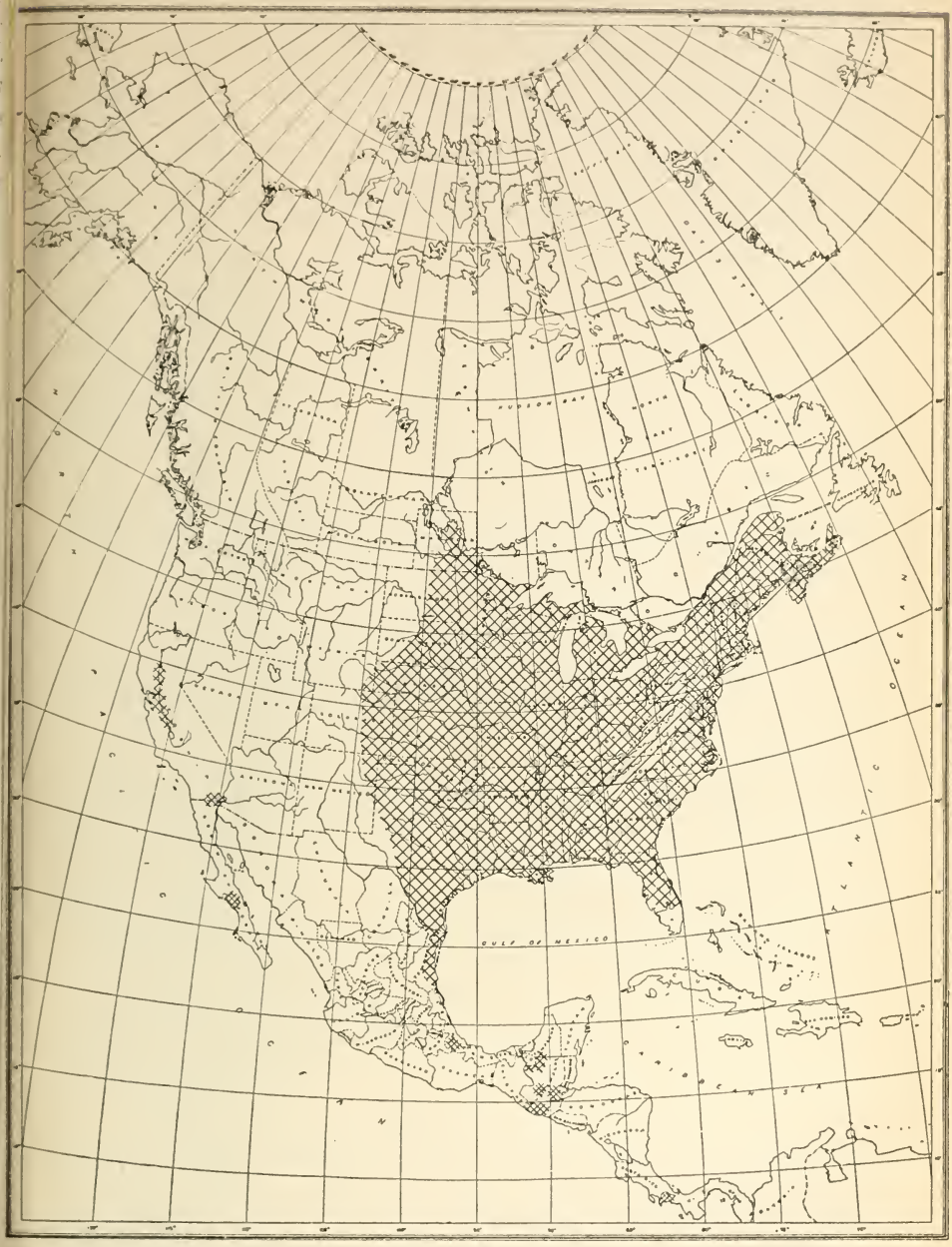


FIG. 1.—Map of North America showing distribution of the chinch bug. (Author's illustration.)

sufficient to justify him in asserting it as a fact or to satisfy him of its correctness.

It therefore seems probable that no young are produced as a result of the late pairing, at least until spring, and it has yet to be shown that the late appearing larvæ do not mature before the hibernating season sets in, or else die during the winter. When we come to consider the extreme susceptibility of the newly hatched chinch bug to wet weather, less perhaps in case of the short-winged form, it will be apparent that as we approach the Tropics the wet and dry seasons would tend to influence the breeding seasons, as those individuals that hatched before the close of the rainy season would be, in a measure at least, continually eliminated, while those that hatched so late as to be caught in the commencement of the rainy season would also be to an equal extent destroyed, and thus, by continually restricting the breeding period to certain months, establish a fixed law that would be adhered to even under the somewhat different conditions which occur farther to the northward. Unfortunately the date or dates on which the young were observed by Mr. Champion, on Volcan de Chiriqui, in Panama, are unknown to the writer, and it is impossible to say whether or not they were found during or near the dry season.

In an article on the hibernation of the chinch bug, Mr. C. L. Marlatt[a] calls particular attention to the fact that in Kansas the chinch bug in autumn seeks the dense stools of some of the wild grasses in which to hibernate, and to such an extent did this occur that it was suggested as probably the normal hibernating habit of the species.

Before entering into a discussion of this matter, it will be well to present two communications received from the late Dr. J. C. Neal, at that time of Stillwater, Okla. As Doctor Neal was located in a section of the country where, in many cases, civilization had not influenced to such a marked degree the natural insect fauna, the author applied to him to secure some exact information in regard to the chinch bug under such conditions. The correspondence, however, was terminated suddenly by Doctor Neal's death. The two letters here given are among the last he ever penned. They are of a somewhat general nature, and will be referred to later in this discussion.

OKLAHOMA AGRICULTURAL AND MECHANICAL COLLEGE,
Stillwater, Okla., October 31, 1895.

MY DEAR SIR: Yours of the 28th just received. Last year was the first wheat year in most of the new additions to this Territory, and from all sections the cry was for infection, as "the bugs are ruining us." I received letters from every county in the strip and in the western sections. The most damage was done in the extreme southern range of counties, and near Okarche (see map, fig. 10) the damage was excessive. I do not think there is a single acre in this or Indian Territory that is not saturated, so to speak, with the chinch bug. You may put this whole area down as within the infested boundary line. My belief is that the increase of country roads, the decrease of March fires, the shiftless habits of the vast majority of our farmers in allowing volunteer

[a] Insect Life, Vol. VII, pp. 232–234, 1894.

wheat and oats to grow and wheat lands to remain fallow, and the planting of new and better grass crops than the tough blue-stem, are direct causes of what I believe a decided increase of this insect in Oklahoma during the last five years. It would be amusing, if it were not so pathetic, to read the many letters I get, something in this wise: "I planted wheat on sod land; the chinch bugs destroyed it so badly that in February I plowed it up and sowed oats; this, too, went the same way; I then planted corn, and when it was a foot high the little bugs came by the millions and destroyed that; I then planted the land to Kafir corn, and that will be ruined if you can not help me." What could I do for such a man? Had the bugs laid out a programme for their daily sustenance, no better commissary-general could have been obtained for them than he was, and I had to write him that his plan was the worst one possible for him, and the best for the bugs, and that the only suggestion I could make, from the bugs' standpoint and for their benefit, would be to plant wheat again so that they could have something for the coming winter's food. In his case it was a series of fatal mistakes from ignorance of the habits of the bugs.

Another thing which I believe adds materially to the increase of these pests is the complete destruction of the prairie chickens, the decimation of partridges, and the thinning out of all kinds of smaller birds, such as the cow blackbirds, bank sparrows, martins, larks, and other prairie birds. This section is full of reckless boys and men who kill everything that flies, good, bad, and indifferent, "for fun."

Some years ago I went out on the Cherokee Strip, miles away from human habitation, and saw some of the small birds—larks and killdees—busily picking in the young grass, in early spring, and upon examination found these places swarming with chinch bugs sucking the juices of the blue-stem grass.

Almost any time in the winter when the weather is warm one can find chinch bugs, and I have witnessed two "flights" of these insects and determined them. I should be glad to answer any more specific questions at any time.

With regards, I remain,

J. C. NEAL.

The second letter is a short note in reply to the author's question regarding the grasses fed upon by the chinch bug, their hibernating habits, and developments:

STILLWATER, OKLA., *November 20, 1895.*

DEAR PROFESSOR WEBSTER: In reply to your postal, I would say that I do not know, but will at once make observations and report at my earliest chance.

My belief is that the bugs attack all the grass family except the Cenchrus, and that only is exempt on account of its bitter taste, which effectually shields it from insects, as far as I have seen, both in this section and in Florida.

I will take the matter in hand at as early a date as possible and write you progress and results.

Very respectfully, J. C. NEAL.

It is reasonable to infer from these letters that the chinch bug wintered over about the stools of grass, and that the birds were observed to attack them there in early spring, as the statement is made that later, when the young corn was a foot high, the little bugs came by the million. This condition of affairs may be considered in connection with the statements of Dr. Asa Fitch,[a] regarding his observations

[a] Second Report on Noxious, Beneficial, and Other Insects of New York, p. 283.

in Illinois in the autumn of 1854, when in passing over the northern part of the State he found the ground in some places, in the midst of extensive prairies, covered and swarming with chinch bugs, reminding him, as he says, "of the appearance presented on parting the hair on a calf that has been poorly wintered, where the skin is found literally alive with vermin." Further along in his report (p. 290) he states that "so late as the forepart of October I met several of these insects in the pupa state, and some of these I do not doubt would pass the winter in that state, and therefore would not deposit their eggs until the following spring." That he did not find these pupæ in New York is shown by his statement on page 287 of the same report, to the effect that he had "met with but three specimens in New York, occurring on willows in the spring of 1847 and May 12, 1851." As shown farther on in this bulletin, there is no proof that these pupæ did not develop to adults before winter, or die before spring, and the conditions indicated would almost presuppose that hibernation would take place on the prairies where the insects were observed by Doctors Fitch and Neal. From personal recollection the writer knows that the section of Illinois to which Doctor Fitch refers was, at the time mentioned, but thinly populated, and there were still very extensive tracts of the original prairie grasses miles distant from woodlands.

In an interesting note by Mr. E. A. Schwarz[a] on the hibernation of the chinch bug, given in discussing Mr. Marlatt's paper, previously mentioned, attention is called to the fact that the hibernation of the chinch bug had been observed by him, in its maritime home, in the vicinity of Fortress Monroe, Va., which locality he had been in the habit of visiting for a number of years, during the first warm days of spring. The maritime flora and fauna are here late to awake, and most insects peculiar to the seacoast can still be found in their winter quarters by the end of April. By pulling up any good-sized stool of grass and beating it out on the smooth surface of the sand or over a cloth a multitude of various insects are sure to be found, and among them always plenty of chinch bugs. These stools of grass not only serve as winter quarters, but in summer the chinch bugs crawl into them during the daytime to protect themselves from the fierce rays of the sun.

In the timothy meadows of northeastern Ohio the writer has witnessed cases where the chinch bugs had commenced their operations along one side, worked part way across the field, killing the timothy as they advanced, and continued their depredations the following year precisely where they suspended work the autumn before, the long-winged individuals only migrating in the intervening time.

[a] Insect Life, Vol. VII, pp. 420–422, 1895.

In southwestern Maine, where this short-winged form has occurred in more or less destructive numbers for upward of forty years, and where it affects timothy in the same manner as in Ohio, both long and short winged individuals, the latter in the majority, hibernate under dead leaves, brush heaps, and similar débris in and about the fields where they have ravaged the timothy. They do not appear to select only the drier portions of such fields, but are found also literally swarming about the clumps of rushes (Juncus) that grow in the low spots. Some of these low places become submerged in winter by rains and melting snows, and the hibernating bugs are washed out and killed.[a] Possibly others not observed might have remained among the living timothy, as it is further stated that many hibernating individuals were to be found among the leaves of clover bordering on spots of timothy that had been killed out by them during the preceding summer.

That the short-winged or maritime form must hibernate in or in very close proximity to the field it infests goes without saying, and it would appear that but for the cultivation of timothy it would have become diffused inland from the coast less rapidly, if at all. It is doubtful if this inland diffusion began until the country became settled by the white man and timothy began to be grown by him as a forage crop—a situation that would be coexistent with a dimunition in the number and extent of prairie and forest fires.

West of the Allegheny Mountains we encounter this short-winged maritime form only in western Pennsylvania, northern Ohio, southern Michigan, extreme northern Indiana, and equally extreme northern Illinois. The writer once found a single short-winged individual in southern Ohio, and a single individual that may or may not belong to this species has been recorded from New Mexico by Prof. T. D. A. Cockerell.*

Except as indicated in the preceding paragraph, over this whole country the long-winged form is the only one known, and its habits are almost as unlike those of the maritime form as they would be were the latter a different insect. Timothy culture has never extended to the Gulf coast, and the extensive growing of the crop over this whole western country is of recent date, coexistent with the advent of the white man. Here, therefore, timothy is not attacked by chinch bugs.

The inland or long-winged form inhabits largely a prairie country, and it would appear that, as these prairies were annually burned over during the hibernating season, the form that became the most scattered prior to hibernation would be likely to stand the best chance of surviving. It seems to the writer that the wings of the chinch

[a] Nineteenth Ann. Rept. Maine Agric. Exp. Sta., 1903, pp. 41–52.

bug might have been, in early days in the Mississippi Valley, kept up to a high standard of development by the necessity of such an escape from prairie fires and not by the presence of *Sporotrichum globuliferum*, as suggested by Professor Sajö in his paper, a translation of which is included herein under the heading, "Habits of the European species, *Blissus doriæ* Ferr."

As mentioned farther on, the advance of civilization having revolutionized the face of the country, there has come a corresponding change in the hibernating habits of the chinch bug. This insect must now seek shelter in the limited patches of timber that are left in the sections that were once entirely wooded and in the matted grass along fences and roadsides, but especially among the fallen leaves and rubbish that usually accumulate along Osage orange hedges. Brush piles, old haycocks, strawstacks, and, in Ohio, at any rate, shocks of corn fodder left standing in the fields through the winter, all harbor chinch bugs during the hibernating season.

The fact that the insect hibernates in matted bluegrass along roadsides and fences has been called in question by Professor Forbes and by Mr. Marlatt, the former in his first report as State entomologist of Illinois (p. 37) and the latter in Insect Life (Vol. VII, p. 232), but notwithstanding this, in some parts of Ohio, in Indiana, and Illinois they do hibernate in just such places and can be found there, especially during the winter and early spring following a season of abundance, but the investigator must know how to search for them. The writer has found them late in the fall collected under rails, half buried in soil and dead grass, and in northern Illinois, while searching for other insects in early spring, he was sure to find them in varying numbers with small Carabidæ, Staphylinidæ, and other early appearing insects, on the under side of boards laid down in grassy places, though no amount of searching the grass itself would have revealed their presence.

In the timothy meadows of northeastern Ohio the percentage of long-winged individuals is always much greater in fall than in June, showing that some, at least, hibernate there and migrate to the cultivated fields in spring. In Maine, in the case of the maritime form, of 565 bugs collected in hibernation in October, 1902, only 60 had long wings.[a] In Kansas, where Mr. Marlatt made his observations, there was still too much prairie, and the species was doubtless still adhering to its ancient habits of hibernation. In southern Ohio the author has found it attacking the wheat in May, in small isolated spots over the fields, while there was nothing in the least to imply an invasion from outside, but the wheat had been sown in the fall among corn, and later the cornstalks cut off and shocked, remaining in this condition until the following spring. This occurred so frequently that

[a] 19th Rept. Maine Agric. Exp. Sta., 1903, p. 48.

there seemed no room to doubt that the attacks had been caused by adults wintering over in the corn fodder, and that these left their winter quarters in spring to feed and breed on the grain growing nearest at hand.

Prof. Herbert Osborn,[a] in giving a summary of his observations on the chinch bug in Iowa in 1894, states that "In a great majority of cases, 90 per cent or more, the infested fields were directly adjacent to hedges or thickets or belts of timber, and in 75 per cent Osage orange hedges were the most available shelter. In about 13 per cent of the cases the evidence showed hibernation in grass and weeds, and in some of these cases there could scarcely be a doubt that the hibernating bugs were protected by a heavy growth of grass or weeds and that they moved from these directly into the adjacent grain fields." Prof. Lawrence Bruner had previously called attention to the fact that the chinch bug hibernated in great numbers about Osage orange hedges in Nebraska. Doctor Lugger, in Minnesota, gives the following as offering shelter to the bugs during winter: "Rubbish of all kinds, but chiefly that of hedges, wind-breaks, and along the edges of woods, as well as corn fodder, logs, and even loose bark and stones."

While drenching rains are beyond all possible doubt fatal to the newly hatched young, the adult bugs seem to be almost proof against either wet or cold weather. It is doubtless true that very many individuals die in their winter quarters, and in fact the writer has found these dead in considerable numbers in some instances during early spring, but it seems at least doubtful if either cold or wet would entirely account for this fatality. It would seem that somewhere and at some period in the past this hibernation has been more for protection from natural enemies than against the elements, though of course there might have been other reasons not discernible under a changed environment. The pupa hides away to molt, though it does not appear that this course is followed in the earlier stages, and the reasons for this are not at all clear. That the adult is able to withstand combined cold and wet weather is amply proved by the observations of several people. Dr. Hy. Shimer, in Illinois, found that those which were in corn husks filled with ice, even the chinch bugs themselves being inclosed in the crystallized element, were able to run about when they were thawed out, apparently unaffected by a temperature that had varied from 15° to 20° below zero Fahr. It seemed that when exposed to the sweeping prairie winds at that temperature, with no protecting cover, they perished. Mr. G. A. Waters, in the Farmers' Review for October 19, 1887, relates that a bunch of fodder that had fallen into a ditch washed out near a corn

[a] Chinch Bug Observations in Iowa in 1894, Insect Life, Vol. VII, pp. 230–232.

shock by heavy rains became covered with water that stood over it long enough for a sheet of ice to form. When the water had subsided the corn was husked and a number of chinch bugs were found among the ears, where they had been immersed for a week or more; yet on being exposed to the warm sun they began to crawl about in a lively manner.

The Maine Agricultural Experiment Station some years ago[a] carried out a series of experiments with the maritime form to determine the effect of freezing. Ten long-winged and 6 short-winged bugs were frozen in an open box for fifteen hours. Upon thawing out 2 gave no signs of life. After being kept for nine hours at a temperature of 65° the 14 surviving bugs were refrozen for fifteen hours and then thawed out, when 5 long-winged and 3 short-winged revived. After nine hours at a temperature of 65° they were frozen a third time for fifteen hours, during which time the minimum temperature sank to 16° below zero. When thawed out all revived, but during the following nine hours at 65° temperature the 3 short-winged bugs and 2 of the long-winged ones died. The remaining 3 long-winged were then frozen a fourth time for fifteen hours, after which none revived.

In summarizing the results of these experiments, 25 in number, it was found that complete submersion in water, even for a considerable period, is not necessarily fatal. Freezing during submersion in water is almost surely fatal. Freezing while exposed to dry atmosphere is generally fatal. Freezing in a moisture-laden atmosphere is only occasionally fatal. It will be observed, however, that not all of these results would necessarily follow corresponding experiments with the inland long-winged form.

SPRING, SUMMER, AND AUTUMN MIGRATIONS.

If there is an ample supply of proper food close at hand the chinch bug simply crawls from its hibernating place, but if it is in the timothy meadows of northeastern Ohio it does nothing but continue its ravages where it left off the autumn before, except some of the long-winged form, which very evidently fly to the wheat and corn fields. In wheat fields—unless the migration has been from an adjoining field, in which case the attack is made along the edge nearest thereto—the females do not seem to forsake their gregarious habits entirely, as they do not scatter out evenly over the entire field, but appear to locate in colonies, and when the young hatch and begin to attack the growing grain their presence is first disclosed by small whitening patches, which increase in dimensions as the young become older and more numerous. In low-lying fields these whitening patches more

[a] Nineteenth Rept. Maine Agric. Exp. Sta., 1903, p. 48.

commonly appear on the back furrows or on any slight elevations that occur in the field. But on higher and level ground the whitening areas are observed scattered over the entire field, and constantly widening until the whole field appears to ripen prematurely and crinkle down. When the migration is accomplished by crawling, the females seem to spread only enough to afford food for the young until the latter are able to make their own way from place to place. The young remain clustered on the plant about which they were hatched until this has been drained of sap, when they make their way, almost in a body, to a second plant, and in this way an attack will be pushed forward day after day.

In the spring the chinch bug probably lingers about its winter quarters until a favorable day for migration occurs. Transfer a typical Indian summer day to early May, and perhaps raise the temperature a few degrees, and you have a day during which chinch bugs may be seen on the wing, crawling along on fences, or at rest on the tops of fence posts as if taking observations, and in reality, as the writer has come to believe, to catch the scent of wheat or corn fields. It is on just such a day as this that *Aphodius serval* Say will be observed posted in precisely the same way, opening and closing the leaves of its antennæ, evidently to catch the scent of the fresh droppings of animals. The same movements characterize *Aphodius inquinatus* Hbst. during the Indian summer days of autumn. The writer has also observed the plum curculio, *Conotrachelus nenuphar* Hbst., acting in precisely the same way in late autumn.

While discussing the subject of chinch-bug migrations, it may be best to state here that there is a second flight of chinch bugs in summer after the majority have become fully developed, and not as soon as the individual reaches the adult stage, as Professor Sajö has found to be the case with the European species, *Blissus doriæ* Ferr. A migration by flight takes place in the fall, usually during the period of Indian summer. The magnitude of such migrations depends in the spring on the number of individuals that have been in hibernation, and in the summer and fall entirely on the abundance of the species during the current year. If there has been no great abundance during the spring the summer flight will not be likely to attract attention. During the invasion of 1896 in Ohio an individual alighted on the writer's hand while he was riding on a street car in the heart of the city of Columbus. A heavy storm of rain has much influence in scattering the bugs in midsummer, and just preceding a heavy rain the writer has noted the fully developed adults very abundant on Indian corn plants, while immediately after the storm there would be very few to be found. As these storms were not always accompanied by high winds, it is probable that it is the rainfall that scatters the insects.

In timothy meadows where the original attack has begun along one side and gradually extended inward, the line of separation between the entirely dead grass and that uninjured is frequently not over a yard in width, and within this narrow, irregular strip we may have the dead and brown, the yellowing indicating more or less serious injury, and the perfectly healthy green of unattacked plants. This many-colored border may change but little in the space of a week or ten days, except to advance very materially, leaving the grass completely dead or dried up, while the clover plants are uninjured. This indicates that the females, after leaving their places of hibernation, do not spread out over any large area, but to a certain degree maintain their gregarious habits. The author believes that these habits have been shaped by some past environment in which the species has been placed for a long period of time, as, for illustration, the inhabiting of bunches or tufts of grass more or less isolated from each other.

To what extent pairing takes place in these places of hibernation before the insects make their way to the cultivated crops is a matter of considerable uncertainty. From his own observations the writer is inclined to believe that only a very insignificant minority follow this course.

In his "Wanderings of Insects" Prof. Karl Sajö has called attention to the influence of electrical storms in the dispersal of insects, and it is quite possible that adult chinch bugs may be thus affected by the heavy thunder that usually accompanies these storms, during which they seem to disappear from corn plants on which they had previously congregated.

OVIPOSITION.

According to most writers the eggs are deposited either about or below the surface of the ground, among the roots of the grass or grain. It is more than likely that the place varies with the conditions, as the eggs are not infrequently found above ground about the bases of the plants, and even upon the leaves, though we have never found them there, but have often found them under the sheath of grasses. It would seem, then, that the eggs require a cool, damp, but not a wet location.

EGG PERIOD AND NUMBER OF EGGS DEPOSITED BY EACH FEMALE.

Doctor Shimer states that each female deposits 500 eggs, scattering them over a period of from ten days to three weeks, and as the adult develops in fifty-seven to sixty days after the eggs are deposited, or about forty-two days after hatching, it will be seen that some of the earliest hatched young are well along toward full development by the time the last eggs are being deposited. According to Doctor Riley, the eggs hatch, on the average, in two weeks.

In a series of breeding-cage experiments Prof. W. G. Johnson found that each female deposited from 98 to 237 eggs, the egg period lasting from eighteen to twenty-one days, and the period of oviposition covering from thirty-eight to forty-two days. Forbes also records in his Fifth Report (p. 44) experiments showing that the period of incubation may cover from twelve to twenty-two days. (See Forbes's 19th Report, pp. 177–183.) It must be remembered, however, that Professor Johnson had but six females employed in his experiments and that these were necessarily under an artificial environment.

DESCRIPTIONS OF THE DIFFERENT STAGES OF DEVELOPMENT.

The following descriptions of the egg and various stages of the young bugs are taken from Riley's Seventh Missouri Report, while that of the adult is from the original by Thomas Say, as published in his American Entomology (Vol. I, p. 329, Le Conte Ed.):

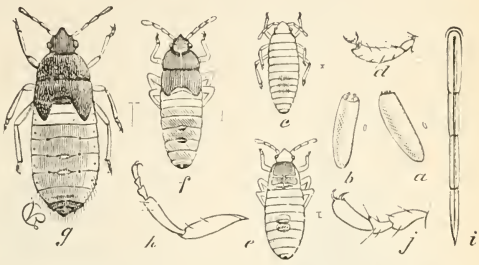


FIG. 2.—*Blissus leucopterus: a, b,* eggs; *c,* newly hatched larva; *d,* its tarsus; *e,* larva after first molt; *f,* same after second molt; *g,* pupa; the natural sizes indicated at sides; *h,* enlarged leg of perfect bug; *j,* tarsus of same, still more enlarged; *i,* proboscis or beak, enlarged. (From Riley.)

The egg.—Average length 0.03 inch, elongate-oval, the diameter scarcely ⅓ the length. The top squarely docked and surmounted with four small rounded tubercles near the center. Color, when newly laid, pale or whitish, and translucent, acquiring with age an amber color, and finally showing the red parts of the embryo, and especially the eyes toward tubercled end. The size increases somewhat after deposition, and will sometimes reach near 0.04 inch in length. (Fig. 2, *a, b.*)

Larval stages.—The newly hatched larva is pale yellow, with simply an orange stain on the middle of the three larger abdominal joints. The form scarcely differs from that of the mature bug, being but slightly more elongate; but the tarsi have but two joints and the head is relatively broader and more rounded, while the joints of body are subequal, the prothoracic joint being but slightly longer than any of the rest. The red color soon pervades the whole body, except the first two abdominal joints, which remain yellowish, and the members, which remain pale.

After the first molt the red is quite bright vermilion, contrasting strongly with the pale band across the middle of the body, the prothoracic joint is relatively longer, and the metathoracic shorter. The head and prothorax are dusky and coriaceous, and two broad marks on mesothorax, two smaller ones on metathorax, two on the fourth and fifth abdominal sutures, and one at tip of abdomen are generally visible, but sometimes obsolete; the third and fourth joints of antennæ are dusky, but the legs still pale. After the second molt the head and thorax are quite dusky, and the abdomen duller red, but the pale transverse band is still distinct; the wing pads become apparent, the members are more dusky, there is a dark-red shade on the fourth and fifth abdominal joints,

and, ventrally, a distinct circular dusky spot, covering the last three joints. (Fig. 2, *c, d, e, f.*)

The pupa.—In the pupa all the coriaceous parts are brown-black, the wing-pads extend almost across the two pale abdominal joints which are now more dingy, while the general color of the abdomen is dingy gray; the body above is slightly pubescent, the members are colored as in the mature bug, the three-jointed tarsus is foreshadowed, and the dark horny spots at tip of abdomen, both above and below, are larger. (Fig. 2, *g.*)

The adult.—Blackish, hemelytra white with a black spot.

Inhabits Virginia.

Body long, blackish, with numerous hairs. Antennæ, rather short hairs; second joint yellowish, longer than the third; ultimate joint rather longer than the second, thickest; thorax tinged with cinereous before, with the basal edge piceous; hemelytra white, with a blackish oval spot on the lateral middle; rostrum and feet honey-yellow; thighs a little dilated.

Length less than three-twentieths of an inch.

I took a single specimen on the Eastern Shore of Virginia.

The whiteness of the hemelytra, in which is a blackish spot strongly contrasted, distinguishes this species readily.

To the foregoing description of the adult Dr. Asa Fitch, in his second report on the Insects of New York, adds brief descriptions of nine varieties, all, with but one exception, being based upon slight variations in color, some, perhaps, being due to immaturity, the single exception being the short-winged inland form, of which variations from the nearly wingless to fully winged are shown in figures 3 and 4.

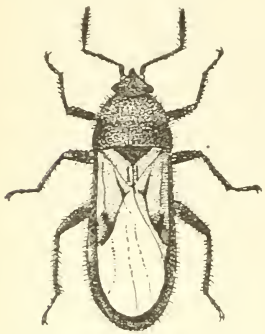


FIG. 3.—*Blissus leucopterus:* adult of long-winged form. Much enlarged (original).

Leaving, then, out of consideration the color varieties as arranged by Doctor Fitch, we have a long-winged form (fig. 3) in which individuals from the eastern portion of the country differ from those found in the West by being more hairy and robust, as pointed out by Mr. Van Duzee, and a short-winged form (fig. 4), found along the seacoast, and in the North Atlantic Coast region, extending inland as far as the country adjacent to the Great Lakes.

DEVELOPMENT AND HABITS OF THE YOUNG.

The newly hatched young are very active, and the first to appear may be observed with their progenitors about the bases of wheat, corn, or grass plants, and later all stages are seen mingling together, having little appearance of belonging to the same species, so greatly do they vary in size and color in their several stages of development.

As a rule the bugs confine themselves to the lower portion of the plants attacked, but may later push their way upward, especially if the lower portion becomes tough and woody, finally covering the plants in

patches, as seen in figure 5, where they are shown on a stalk of young corn. Mr. E. A. Schwarz relates a curious exception to this habit in Florida upon sand oats, *Uniola paniculata*, where the entire development of the insect is undergone upon the highest part of this tall plant and not close to the bottom. Mr. Schwarz has given as a probable reason for this the fact that strong winds are continually blowing the fine, sharp sand through among the lower parts of the plants, rendering it nearly or quite impossible for the bugs to remain in that situation, thus forcing them to seek their sustenance farther up the plants. While figure 5 gives a good representation of the appearance of a corn plant when the chinch bugs are present in excessive numbers, yet the writer has invariably found that these bugs much prefer a stalk that has been blown down by the wind or partly broken off by the plow and left lying nearly flat upon the ground.

In timothy meadows the very young are to be found only by pulling away the soil from about the bulbous roots and drawing down

FIG. 4.—*Blissus leucopterus:* adults of short-winged form. Much enlarged (original).

the dead sheaths that usually envelop them. An observer may even pull up a tuft of grass entire, and yet, unless he examines in this way closely, may overlook them, so snugly are they thus ensconced among the roots. If driven to forsake a tuft of grass the young bugs move to another and crawl downward, and are soon to be found as snugly settled as before. It is only when they are older and well advanced toward maturity that they work to any extent above ground, and even then only in cases where they are present in great numbers. Singularly enough, where infested meadows are plowed up and planted with corn the females seem to ignore the young corn plants and select the occasional stray clumps of timothy that cultivation has failed to destroy and deposit their eggs about these, so that later the young may be swarming about these last, while hardly one is to be found about the young corn. This is precisely the opposite of what is observed farther west.

Although living externally on their food plants, and notwithstanding the fact that the young may attack the bases or even the roots of some of these, the species is essentially an external feeder, and appears while thus engaged almost totally indifferent to possible attacks of natural enemies. When not feeding, however, there is at times a tendency to hide away under the sheaths of young corn or beneath clods of earth or bunches of coarse stable manure, where this has been recently applied and left more or less exposed on the surface of the ground. The writer has noted this in cases where neither an uncomfortable temperature nor wet weather necessitated protection.

As has been shown in the description of the larval stages, there are four molts between the egg and the adult state. Just how the molting larvæ act we have never been able to determine; neither have we witnessed pupation, but a fully developed pupa that is ready to molt is easily distinguished by its larger size and more tightly fitting skin, which is almost shining white on the median ventral surface of the abdomen. It now hides itself away, seemingly preferring to get under the sheaths of grasses or grains; but if these are not convenient it will crawl under loose clods, or even into crevices in the ground. While thus hidden away the pupa skin splits along the back and the fully developed adult makes its way out, leaving the empty skin behind. These last are very frequently mistaken for dead chinch bugs, and, when moldy, the farmer is very likely to suppose that they are bugs which have been killed by the fungus *Sporotrichum globuliferum*, if this has been applied in the fields.

On first emerging from the pupa the adult is generally of a dull pink color, except the wings, which are white, exclusive of the veins; these being of the same pinkish hue as the body. In a short time these colors change to the normal ones of the species, but during the breeding season these newly developed adults may be observed crawling about with the young of all stages as well as the maturely colored adults.

If this development has been taking place in a wheat field and the grain is harvested at this time, or if from any other cause the food supply becomes suddenly exhausted, all sizes of larvæ with pupæ and adults will start off on foot to hunt for a fresh supply. Though many individuals may now have become fully developed, and, so far as can be determined, possess wings entirely fitted for active service, nevertheless they will crawl along a dusty road or across freshly plowed fields in company with their less fortunate fellows, seemingly never for a moment supposing that they can span the intervening space by flight. The writer is totally unable to account for this phenomenon in the species at this time, the disinclination to use the wings being so wholly unlike the habits of *B. doria*, as shown by the careful and painstaking observations of Professor Sajó in Hungary. Again,

the seeming desire on the part of the pupæ to secrete themselves while transforming to adults does not at all coincide with the idea of a supposed immunity from attacks of natural enemies. Surely our species of Blissus has not always lived where natural enemies were as few as they are with us at the present time. Even where we have both the long-winged and short-winged forms occurring together in timothy meadows there is no such haste exhibited on the part of the former to escape from the companionship of the latter, as observed by Professor Sajö. We know, however, that our species certainly does enjoy a considerable immunity from natural enemies, though its conspicuous colors in both the larval and adult stages contrast very strongly with those of its usual food plants and its presence is still further advertised by its strangely persistent gregarious habits. We have come to suppose the species to be, in part at least, protected from attack by its vile odor, and so, indeed, it may be in the United States, but the writer fully believes that somewhere in its southern habitat it will be found to have one or more enemies, like the ant, *Eciton hamatum* Fab., of Central America, for illustration. Our native ants, however, will seldom attack even the young.

NUMBER OF GENERATIONS ANNUALLY.

Over the most of its area of habitation in North America, at least, the chinch bug is two brooded, though in northeastern Ohio the writer has totally failed to detect the second brood, or, in fact, to perceive any indications that a second brood occurs; but this will be referred to later. As previously shown, there is not sufficient proof at hand to warrant the statement that there is, even in the far South, a partial third brood. It is probable that the number of broods of this species annually has been primarily decided in its home in the tropical regions by the wet and dry seasons occurring there, and that we have in the North these same broods occurring at slightly different periods under the influence of a change from wet and dry to hot and cold seasons.

Belt, in his Naturalist in Nicaragua, has the following to say with regard to the seasons on the northeastern side of that country: "The rains set in in May and continue with occasional intermissions until the following January, when the dry season of a little more than three months begins" (p. 103). "The heaviest rains fall in July and August, and at those times the brooks are greatly swollen." "In September, October, and November there are breaks of fine weather, sometimes lasting for a fortnight, but December is generally a very wet month, the rains extending far into January, so that it is not until February that the roads begin to dry up" (p. 104). It seems that possibly we have here the key to the secret of the number of

broods annually of the chinch bug. That this insect may be able to adapt itself still further to changed latitude and environments and become single brooded is not at all impossible. As illustrating the ease with which insects, at least some of them, can change their habits to correspond with their environment, we have in South Australia the following facts regarding the codling moth, *Carpocapsa pomonella* L., of which, though being still double brooded, "the winter caterpillars hatch into moths irregularly from the beginning of October until the middle of November and deposit their eggs accordingly, giving rise to a succession of young caterpillars until the beginning of December. About the third week in December the first moths of the second brood begin to appear and deposit eggs, and members of this second generation of moths continue hatching and egg laying until the end of February."[a]

The author's notes on the chinch bug in northeastern Ohio are as follows: Very young larvæ, with what appeared to be their progenitors, were observed at Jefferson, Ashtabula County, within 11 miles of the shores of Lake Erie, June 16, 1893, there being no advanced larvæ among them. On August 27, 1896, a few miles south, at West Andover, in the same county, only adults were observed in two days' search, though some of these showed by their color that they had but recently passed the pupal stage. In this latter locality, May 7, 1897, the sexes were pairing, but no young were present so far as could be observed, while to the south and west of this locality, June 8 and 9, precisely the same conditions obtained as to the bugs, no young appearing at this time. Quite copious rains might have destroyed the young, but within 15 miles of these localities, on July 14 of this year, larvæ were found after first molt and stages intervening between these and the adults. Near Youngstown, on October 3, 1897, only adults were present, pairing was not in progress, and the insect was not pairing in Ashtabula County on August 27, 1896. June 9, 1898, only two very young larvæ could be found at Salem, about 15 miles southwest of Youngstown.

Up to October 17, 1898, no young of a second brood had been observed, though careful search had been made from time to time in the fields and meadows of northeastern Ohio, and a large number of adults which developed in July and August, and since kept in confinement, had not only not reproduced, but had shown no disposition whatever to pair. On the other hand, in southwestern Ohio, in the vicinity of Cincinnati, on September 24, where the species occurred in abundance, fully 75 per cent were pupæ, the remainder being made up of larvæ, some of them quite young, and adults in about equal

[a] George Quinn, in Journal of Agriculture and Industry, South Australia, Vol. I, p. 112.

proportions, some of the latter showing by their immature colors that they had but just passed the pupal stage.

Hatching is not fully in progress in the Northeast before the 25th of June, only an occasional individual having passed the first molt before the 10th of July. In the light of the information that has been gained by these observations, the occurrence of a second brood of young in northeastern Ohio is doubtful.

The late Dr. J. A. Lintner, in his studies of the outbreak of this insect in New York State in 1882 and 1883, seems to have relied much on the published habits of the species farther west—as, indeed, the writer has himself done until recently—and made no exact studies of the species at that time; and in his annual report, where the outbreak is discussed, no absolute proof of the existence of a second brood in New York is presented.[a] The occurrence of a second brood of young in northern Illinois, as indicated by Doctor Fitch, has always been considered as settled, and in a more northern latitude than northern Ohio, so that there must be some other influences besides latitude to account for the phenomenon. That the species has occupied this territory for many years is indicated by the observations of Mr. E. P. Van Duzee, of Buffalo, N. Y., who wrote that the insect was as abundant twenty-three years ago as at the present time, so that whatever effect on the insect the recent occupation of the country might have had, that effect has passed away and a condition of what we might call equilibrium now exists here.

On July 7, 1889, in the extreme northern part of Indiana, the writer found an abundance of young which had not yet molted for the first time. Dr. A. S. Packard records adults as pairing at Salem, Mass., June 17, 1871, as quoted by Doctor Lintner, while the latter gentleman[b] records the young as occurring in Lawrence County, N. Y., about June 5, 1883.

Hardly have the latest hatched young of the first brood developed to the adult before the young of the second brood begin to appear. In southern Ohio this is about the first week in August. Generally these young do little injury, because the wheat has long since been harvested and the corn is usually too far advanced and tough to offer a desirable source of food supply, except in cases where fields have been planted very late, and here the writer has known them to work considerable injury, especially in seasons of severe drought that prevented the rapid growth of the plants. Fall attacks on wheat are rare, and the injury is never of a serious nature, as it is usually the case that by the time the young wheat is large enough to invite attack the chinch bugs are searching for winter quarters.

[a] Second Report State Entomologist of New York, pp. 148–164, 1885.

[b] Loc. cit., pp. 158, 159, 164.

In the timothy meadows of northern and northeastern Ohio, however, the principal injury is done during August and September, and in favorable weather on into October. Now, if we allow sixty days for development from the egg, it would be September before the appearance of the adults of the brood to which these various young belonged. If all eggs were deposited immediately, it would be November before the adults of the second brood would begin to occur, a condition of affairs that has never been observed. As previously shown in this bulletin, the first brood is fully developed in northeastern Ohio by the first of September, but there certainly is no indication that a second brood of young is developed during September and October. It would seem, then, that from northern Ohio through New York, New England, and probably to Nova Scotia the adults from the first brood of larvæ winter over, and that there is here but one annual brood.

DESTRUCTIVENESS LARGELY DUE TO GREGARIOUS HABITS.

Attention has been directed previously to the gregarious habits of the chinch bug, and we only refer to the phenomenon again because it is to this that its destructiveness is largely due. It is not the excessive numbers, but the persistency with which they will congregate *en masse* on limited areas, that renders their attacks so fruitful of injury. With an ample supply of food the young develop and leisurely diffuse themselves over the adjacent fields, and there are neither swarming flights nor migrations. In 1884, in northern Indiana, a small field of wheat was severely attacked by chinch bugs. At harvest there was every prospect of a migration from the field of wheat to an adjacent one of corn, and the bugs were present in sufficient numbers to have worked serious injury to the latter; but the wheat had grown up thinly on the ground, and there had sprung up among the grain a great deal of meadow foxtail grass, *Ixophorus* (*Setaria*) *glaucus*, and panic grass, *Panicum crus-galli*, and to these grasses the bugs transferred their attention, finishing their development thereon, and later, so far as could be determined, they scattered by flight out over the adjacent fields, working no further injury. Pedestrian migrations may continue for a fourth of a mile or even more, but on reaching a suitable food supply the tendency of the bugs is to congregate upon their food plants until these are literally covered with individuals varying in color from the black and white of the adults to the bright vermilion of the more advanced larvæ. (See fig. 5.) Whatever tendency there is exhibited toward a wider diffusion is confined to the adults, the others remaining and leaving in a body only when the plant on which they have congregated has been drained of its juices and has begun

to wither, when they simply crawl to the nearest plants and again congregate upon these as before. In case the migration has been to a field of corn, if this is badly overgrown with either of the two grasses previously named, the bugs will collect upon the latter, and unless the corn plants are very small they will not as a rule attack them until the grass has been killed. Some farmers have gone so far as to claim that a benefit is derived from a certain abundance of chinch bugs, the statement being made that the bugs will kill out these grasses to an extent that nothing else will. It is clear that the acquisition of wings is not the signal for the adults to abandon the companionship of the larvæ and pupæ, yet they do gradually disappear from among them. It is possible that the disposition to pair does not exist until the individual has reached a certain age beyond seeming maturity, and that it is not until the passion for mating has overcome their gregarious inclination that they are disposed to migrate. Or it may be that the phenomenon may be explained on the supposition that when the pairing season approaches the males scatter out in order to find females with which they are not akin, thus following out natural selection and preventing a continual interbreeding. Over the northern United States, at least, the injury in cultivated fields is done almost entirely by the young bugs, but in the timothy meadows the damage is due as much, if not more, to the depredations of the adults.

FOOD PLANTS.

As to food plants, there can be no doubt that these consisted originally of the native grasses. This is amply proved by the observations of Fitch and Le Baron, in Illinois; Dr. J. C. Neal, in Florida and Oklahoma; Marlatt, in Kansas; Schwarz, in Florida; and by those of Mr. Henry G. Hubbard in the midst of the Colorado desert in California. Regarding this last statement, Mr. E. A. Schwarz wrote as follows:

> You may be interested to learn that chinch bugs were collected this year (1897) on March 28 by Mr. H. G. Hubbard, at Salton, in the midst of the Colorado desert of California. This locality is considerably below the ocean level, and represents an ancient extension of the Gulf of California. Even at the present time the Salton Basin is occasionally flooded, the water entering through New River, which runs from the mouth of the Colorado River into the Salton Basin. The specimens were taken on a species of coarse grass which is incrusted with a saline deposit.

No wonder that the chinch bug is accused of being a seashore species!

Of cultivated grasses, or such as occur in cultivated fields, probably *Lxophorus glaucus* and *Panicum crus-galli* are the favorites, though millet and Hungarian grass are apparently nearly as attractive. As

early as 1845, in Illinois, Dr. William Le Baron, afterwards State entomologist, gave the food plants of the chinch bug as follows:

FIG. 5.—Corn plant two feet tall infested with chinch bugs. (Author's illustration.)

* * * "all kinds of grain, corn, and herd's-grass" (timothy).[a] But to this day in Illinois, as shown by the observations of Professor

[a] Prairie Farmer, December, 1845.

Forbes and the writer, the species will attack timothy only in cases where it is compelled to do so by reason of a lack of other food. In addition to the preceding, Doctor Howard gives broom corn, sorghum, chicken corn, Bermuda grass (*Capriola dactylon*), bluegrass (*Poa pratensis*), crab grass (*Syntherisma sanguinalis*), and bottle grass (*Ixophorus viridis*), and also states that in the rice fields near Savannah, Ga., in August, 1881, he observed the winged adults upon the heads. Prof. H. A. Morgan wrote that in 1897 it had become a serious enemy to "Providence" rice in Louisiana, where for two years it had seriously injured corn, and the writer was informed through other sources that it proved injurious to corn again in 1898. Adults have often been found collected in the silk of belated ears of corn in the fields in September, when all other parts of the plant had either become too old and tough to afford nourishment or else had been killed by the frosts of autumn. Prof. Lawrence Bruner has recorded the insect as feeding upon so-called wild buckwheat (*Polygonum dumetorum* or *P. convolvulus*).[a] The writer has never seen chinch bugs attack bluegrass (*Poa pratensis*), and has seldom witnessed them injuring oats, but on September 27, 1904, he observed larvæ, pupæ, and adults, the last all fully winged, attacking Arrhenatherum (oat grass) on the experiment farm of the University of Tennessee, at Knoxville. Over the western country the major portion of the damage done is to fields of wheat, barley, rye, and corn, the outbreak generally originating in wheat or barley fields and the bugs migrating at harvest to the corn-fields. (See fig. 5.) In the eastern part of the country, where the timothy meadows are the most seriously infested, this is not the case, and here the migrations are as likely to be to the timothy meadows as to the fields of corn, where both are equally within reach. Besides, everything indicates that a very large próportion of the adults may hibernate in these meadows, even making their way thereto in the autumn.

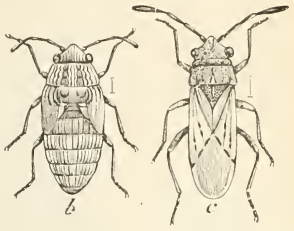


FIG. 6.—*Nysius angustatus*: *b*, pupa; *c*, mature bug. (From Riley.)

INSECTS THAT ARE MISTAKEN FOR CHINCH BUGS.

Messrs. Osborn and Mally[b] have given a list of twelve species of Hemiptera which have been mistaken with more or less frequency for the chinch bug, the list being as follows:

Nysius angustatus Uhl., the false chinch bug (fig. 6), is probably the most frequently mistaken for the true chinch bug, as it often

[a] Report Commissioner of Agriculture, 1887, pp. 57–58.

[b] Bul. No. 32, Iowa Agr. College Exp. Sta., pp. 363–385.

breeds in considerable numbers under purslane, amaranth, etc., and more than any other insect resembles the chinch bug. It is, however, of a light-gray color, which will always distinguish it from its more destructive fellow.

Ischnodemus falicus Say, or the long chinch bug, as it is sometimes called, is much larger and longer than the true chinch bug.

FIG. 7.—*Piesma cinerea.* (From Riley.)

Ischnorhynchus didymus Zett. is more robust, of a light-tawny color, with prominent, glassy wings.

Peliopelta abbreviata Uhl. is, next to the false chinch bug, probably the most often mistaken for the true insect, and especially is this true in localities where the brachypterous form of *Blissus leucopterus* abounds, viz, in timothy meadows. Its broader head and body, however, quickly enables one to distinguish it.

Geocoris fuliginosus Say, *G. borealis* Dallas, *G. bullatus* Say, and *G. limbatus* Stål, according to Osborn and Mally, have all been confused with the chinch bug in Iowa. These are all broader and flatter than the true chinch bug, the head being nearly as wide as the thorax.

Ligyrocoris sylvestris L. is larger than the true chinch bug, and its wings are quite dark instead of white.

Trapezonotus nebulosus Fall. is a trifle larger and its body is not so black as in the chinch bug.

Cymodema tabida Spin. is longer than the true chinch bug, of a light brown color, and the ends of the wings are glassy.

Triphleps insidiosus Say, or the insidious flower bug (fig. 15), as it is more commonly called, is another bogus chinch bug, though an enemy of the true pest, as previously stated.

Piesma cinerea Say, the ash-gray leaf bug (fig. 7), is often mistaken for the true chinch bug, though its form differs greatly from that of the latter. It is often quite abundant, but not in grain fields or meadows.

FIG. 8.—*Corimelæna pulicaria.* (From Riley.)

Corimelæna pulicaria Germ., the flealike negro bug (fig. 8), has been confused with the chinch bug; though it does not in the least resemble the latter, either in form or color, and its confusion is probably to be accounted for by the fact of its being occasionally found in wheat fields in considerable numbers.

Brachyrhynchus granulatus Say (fig. 9) has been mistaken for the chinch bug in Ohio, and in a way that was somewhat amusing. Farmers in southern Ohio, during the winter of 1896–97, were burning over the woodlands with a view to destroying the hibernating insects, when there came several discouraging reports to the effect that such a course would be ineffective, as the bugs were wintering

in the tops of trees, especially where the tops were dead, under the bark and often from 50 to 75 feet from the ground. This was a piece of astounding information, to the writer at least, and it was only after securing specimens that he was able to solve the mystery. This insect, in all stages of development except the egg, hibernates under loose bark. It is broader and much flatter than the true chinch bug, but the wings are white and the body black.

The object in calling attention to these bogus chinch bugs is to prevent their confusion with the true *Blissus leucopterus*, as in some cases people finding them and supposing them to be the true pest are likely to become panic stricken and often destroy property unnecessarily, so notorious has the name "chinch bug" become in the United States.

LOSSES CAUSED BY CHINCH BUGS.

It would appear that this pest first made its presence known by its ravages in the wheat fields of the North Carolina farmers; for we are told that "in 1785 the fields in this State were so overrun with them as to threaten a total destruction of the grain. And at length the crops were so destroyed in some districts that farmers were obliged to abandon the sowing of wheat. It was four or five years that they continued so numerous at this time." [a]

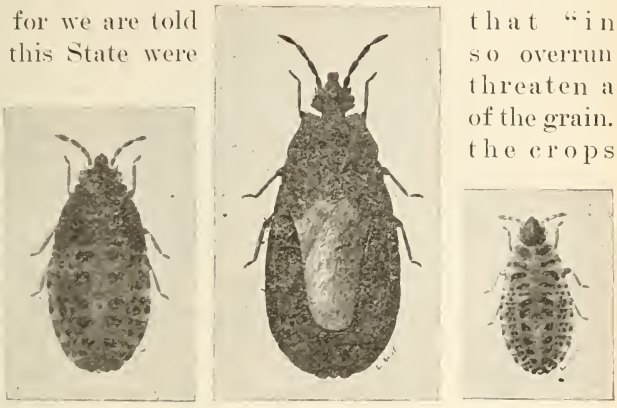


Fig. 9.—*Brachyrhynchus granulatus:* *a*, early nymph; *b*, adult; *c*, late nymph. All enlarged (original).

In the year 1809, as stated by Mr. J. W. Jefferys,[b] the chinch bug again became destructive in North Carolina to such an extent that in Orange County farmers were obliged to suspend the sowing of wheat for two years. In 1839 [c] the pest again became destructive in the Carolinas and in Virginia, where the bugs migrated from the wheat fields at harvest to the corn, and in 1840 there was a similar outbreak, and both wheat and corn were seriously injured. In all of these cases, however, there is no recorded estimate of the actual financial losses resulting from the attacks of the chinch bug. Accord-

[a] Webster on Pestilence, Vol. I, p. 279. Not seen. Quoted from Fitch.
[b] Albany Cultivator, first series, Vol. VI, p. 201.
[c] The Cultivator, Vol. VI, p. 103.

ing to Le Baron, during the years from 1845 to 1850 the insect ravaged over Illinois and portions of Indiana and Wisconsin, and in 1854 and 1855 it again worked serious injury in northern Illinois. The writer's earliest recollection of the chinch bug and its ravages in the grain fields of the settlers on the prairies dates from this last outbreak. Mr. B. D. Walsh estimated the loss to the farmers of Illinois in 1850 at $4,000,000, or $4.70 to every man, woman, and child living in the State. The earlier outbreaks, though the occasion of smaller money loss, were even more disastrous; for the destruction of the grain crops in those pioneer days not only took away all cash profits, but also deprived the early settlers of their very living, and in some cases reduced them to starvation.

In 1863, 1864, and 1865 the insect was again destructive in Illinois and other Western States, its ravages being especially severe in 1864, when we have another attempt at computation of the financial loss. Dr. Henry Shimer, of Mount Carroll, Ill., who had carefully studied the chinch bug, estimated that "three-fourths of the wheat and one-half of the corn crop were destroyed by the pest throughout many extensive districts, comprising almost the entire Northwest." In criticising the doctor regarding another point, Messrs. Walsh and Riley, in The American Entomologist (Vol. I, p. 197, 1869), admit that the estimate was "a reasonable one," and, taking it as a basis, with the actual cash price per bushel, computed the loss at about 30,000,000 bushels of wheat and 138,000,000 bushels of corn, with a total value of both amounting to over $73,000,000. Of course all computations of this sort are necessarily only approximately correct, but there is more likelihood of an under than an over estimate in this case.

There was a serious outbreak of the chinch bug in the West again, in the year 1868, and again in 1871, but in 1874 the ravages were both widespread and enormous. Doctor LeBaron computed the loss in 1871 in seven States, viz, Iowa, Missouri, Illinois, Kansas, Nebraska, Wisconsin, and Indiana, at $30,000,000.[a] Doctor Riley computed the loss in Missouri alone in the year 1874 at $19,000,000, and added the statement that for the area covered by Doctor LeBaron's estimates in 1871 the loss in 1874 might safely be put down as double, or upward of $60,000,000.[b] Dr. Cyrus Thomas, however, estimates the loss to the whole country for the same year at upward of $100,000,000.[c]

The next serious outbreak of the chinch bug of which we have the losses resulting therefrom computed, occurred in 1887, and covered more or less territory in the States of Kentucky, Ohio, Indiana,

[a] Second Report State Entomologist of Illinois, p. 144.
[b] Seventh Report State Entomologist of Missouri, pp. 24–25
[c] Bulletin No. 5, U. S. Entomological Commission, p. 7.

Illinois, Wisconsin, Minnesota, Iowa, Missouri, and Kansas. In this case the damage was estimated by the United States statistician, Mr. J. R. Dodge, at $60,000,000, the heaviest losses occurring in Illinois, Iowa, Missouri, and Kansas.[d] This gives us as the estimated loss in the thirty-eight years, 1850 to 1887, both inclusive, the enormous sum of $267,000,000.

There was a serious outbreak in Kansas, Iowa, Minnesota, and Illinois, having its beginning probably as early as 1892, but reaching its maximum severity, as in Ohio, in 1896. The loss in Ohio during the years 1894, 1895, 1896, and 1897 could not have fallen far short of $2,000,000. The farmers of this State in many cases were entirely

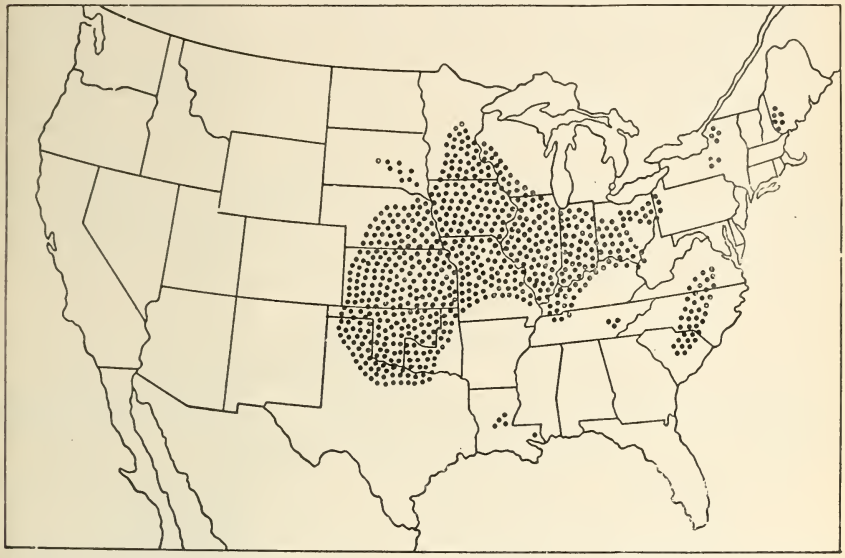


FIG. 10.—Map showing areas in the United States over which the chinch bug occurs in greatest abundance and may at any time become destructive. (Original.)

unfamiliar with the chinch bug and its ravages, and therefore were unable to account for the damage that it worked in their fields until some time after. This was especially true of the timothy meadows in the northeastern part of the State; so that there were probably many fields, both of grass and of grain, that suffered seriously, and, in fact, in some cases were ruined by the chinch bug without the owners being aware of the cause. For this reason, while the computed loss appears large, it seems to me to be entirely reasonable. Of the losses occasioned in other States during the years above indicated no definite computations are available, but they were severe, and must have amounted to millions of dollars. If we could have careful estimates of the loss during the last fifteen years, it would in all probability

[d] Report of U. S. Commissioner of Agriculture, 1887, p. 56.

swell the amount to considerably in excess of $330,000,000 for the period from 1850 to 1906. Within the last ten years the insect has become more injurious in Oklahoma, western Kansas, and northern Texas, localities not included in these estimates, and although the spring rains serve to destroy the young bugs, outbreaks in northern Texas and Oklahoma are not rare in fields of wheat, corn, and barley. If the indirect losses were to be added, the amount would indeed be enormous. During the outbreak in Ohio at least two farmers became discouraged, and, thinking that the loss of their crops by the attack of chinch bugs would result in their financial ruin, in their despondency they sought relief in suicide.

When we take into consideration that the financial losses as above estimated have not fallen upon the entire nation, but almost without exception upon the nine States previously named (see fig. 10), it will be seen that this diminutive insect constitutes a formidable enemy to the agriculturist of these States. In fact, small as it is, this pest has cost the people of these nine States a sum of money which, a few years ago, would have defrayed the entire expense of the National Government for a whole year. Fire excepted, there is probably no other factor that has caused such an enormous financial loss within the same period over the same area of country.

NATURAL CHECKS.

All adverse natural influences affecting the chinch bug will be treated under this head, with the exception of animal and vegetable foes, which are considered here as natural enemies.

INFLUENCE OF PRECIPITATION ON THE CHINCH BUG.

There is probably no more potent factor in restraining the increase in numbers of this species than is to be found in meteorological influences consequent upon rain. The fact has long been known that the years of greatest abundance of the chinch bug were preceded by a series of years during which there had been a deficiency in the rainfall over the area of country devastated by this species. In fact, it has in a general way come to be understood that dry seasons are favorable and wet seasons unfavorable for the development of the chinch bug, though the details of the phenomenon have never been very carefully and elaborately worked out. The entomological and meteorological records of the past have, however, clearly shown that the amount of the annual rainfall is not a safe guide in this problem. Chinch bugs have occurred in excessive numbers during years of heavy precipitation.

The term "wet season," so frequently used in this connection, is an indefinite one, but if the term "season" be restricted to the period of time intervening between the vernal and autumnal equinoxes we shall

have more definite grounds upon which to base our studies of meteorological influences. Thus applied, the terms "wet" and "dry" seasons would include within them the two breeding periods of the chinch bug, at least largely so, north of latitude 30° N. But the history of this species has shown that there may be an excess of rainfall during this critical period and that still a sufficient number of insects may develop to work serious injury over considerable areas of coun-

FIG. 11.—Map showing distribution of chinch bug in Ohio in 1896. (Author's illustration.)

try. This is due to two, and perhaps more, causes. In the first place, an unusually heavy rainfall at long intervals, while bringing up the total for a given period, may have but little effect in reducing the number of chinch bugs, while a much less amount of precipitation coming at short intervals and in the midst of the hatching season would cause a far greater mortality among the young. And, in the second place, the precipitation may come at the beginning or even

before the commencement of this breeding season or just at the close thereof, thus enabling the major portion of the young to reach a period in their development wherein they are little, if at all, susceptible to the effects of drenching rains. This was clearly illustrated in southern Ohio during the spring of 1896, and again in 1897. Throughout southern Ohio, in 1896, between latitude 38° 30′ and 39° 40′, as the reports of the United States Weather Bureau show, there

FIG. 12.—Map showing distribution of chinch bug in Ohio in 1907. (Author's illustration.)

had been but very little rain up to May 11, and no general rain until May 25. The effect upon the young bugs, judging from the destruction which they caused, would seem to have been to destroy only the latest to hatch, leaving the earlier developing young sufficiently advanced to withstand the effects of the later and heavier rains. The accompanying map (fig. 11) will show the areas over which chinch bugs were reported marked thus ▨, while the

area seriously ravaged is indicated thus #, showing that the rain came too late in such a section to ward off an outbreak of the pest.

According to the Weather Bureau reports also, the distribution of rain in May, 1897, differed materially from that of the same month of 1896, in that in 1897 the major portion of the rain fell prior to the 15th, the remainder of the month being rather dry, the only general precipitation occurring on the 23d and 24th, with a much

FIG. 13.—Map showing distribution of chinch bug in Ohio in 1894. (Author's illustration.)

lighter rain on the 28th. But here again the amount was insufficient to ward off serious injury, as is indicated by map (fig. 12), the same symbols being used here as before. In this case it was probably the latter portion of the brood that survived, as a personal inspection of the country early in the month failed to reveal the presence of young bugs, though they were certainly present in abundance at a corresponding period of the preceding year.

That the amount and frequency of rain during the month of May has very much to do with the ravages of chinch bugs where sufficient numbers have wintered over to produce the requisite number of young, is further shown by the fact that in 1894 the only locality where serious ravages were committed was in Wyandot County, as shown on map (fig. 13), and this was one of the few areas in Ohio where the precipitation during that month was less than 3 inches.

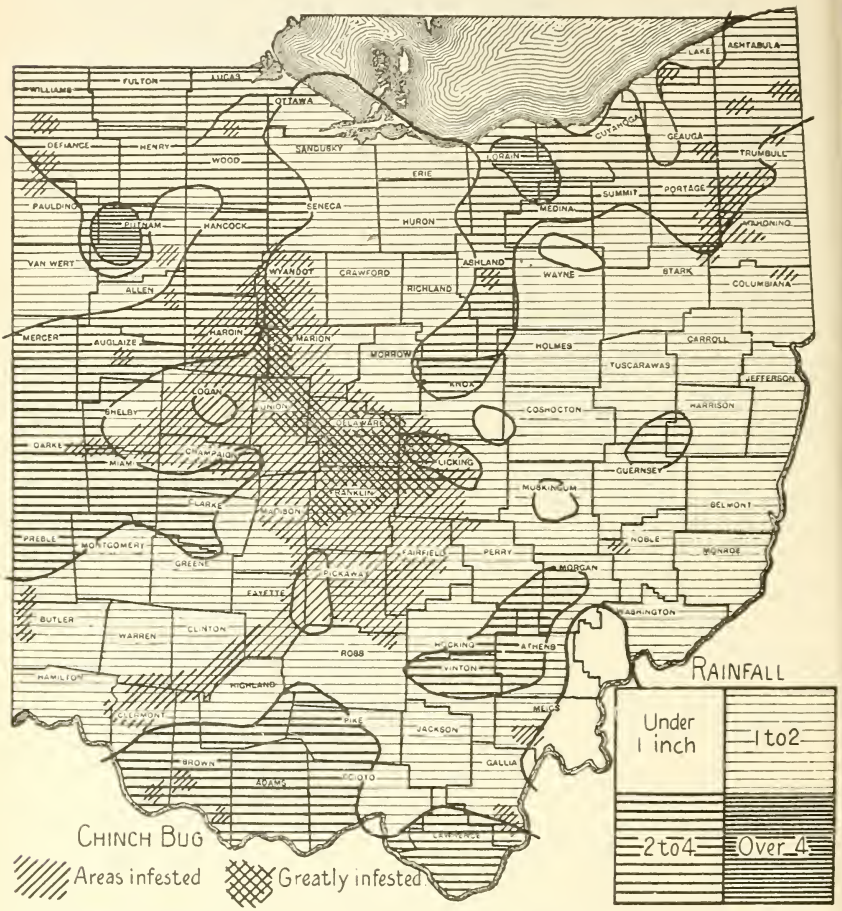


FIG. 14.—Map showing distribution of chinch bug in Ohio in 1895, and amount of precipitation over the State during May of the same year. (Author's illustration.)

Except over a circular area covering less than one-half of the county the amount of precipitation was 3 to 5 inches, and this area includes that ravaged by the chinch bugs during the following month.

Still more striking, however, is the relation between the two phenomena during the following year. The last of this series of maps (fig. 14) shows the area over which chinch bugs were reported

and the area where their injuries were the most severe; also, by horizontal lines, the areas over which the amount of precipitation was the least. From this it will be observed that in all of the seriously affected area, and in nearly all of the area over which the pest was reported at all, the precipitation during the month of May, 1895, was from 1 to 2 inches, the extension of the point westward into Shelby County being especially interesting. It may be said with regard to the occurrences outside of this area of light precipitation that the exact localities were probably not indicated, as the information was secured from farmers, and their locations as indicated on the map were their post-office addresses, which might have been several miles away in any direction, and the isolated points of attack were often based upon one or two reports. If exact localities could have been obtained, and the precise area of precipitation indicated, the connection between the two phenomena would have been shown more correctly, and would probably have revealed an even greater uniformity than is now apparent. It must be understood, however, that in these calculations northeastern Ohio is excluded, and the writer believes that what is true of the rest of the State will be found to be equally correct as regarding territory occupying the same latitude westward to the limit of this area of distribution. While it is probable that the effect of precipitation during August would have a similar influence on the second brood of young, and, consequently, upon the number of adults which would go into winter quarters, yet a careful study of the two factors shows that meteorological conditions in August have a far less influence upon the following brood than do those of May.

Owing to causes which are as yet unknown to the writer the same laws do not apply to the northeastern part of Ohio and to what we have termed the west-bound tide of migration. Here, and as against the more or less short-winged form of chinch bug, meteorological conditions appear to exert a far less potent influence. What is true of meteorological conditions during May elsewhere in Ohio, seems to be partly true of June in the northeastern portion of the State, though there is not the evidence of the effect of precipitation here that we have elsewhere. Doctor Lintner, in his Second Report, while discussing the outbreak of the chinch bug in New York during 1882–83, calls attention to the fact that both in 1881 and 1882 there was an excess of precipitation. On page 158 of his report Doctor Lintner says that spring, summer, and autumn were exceptionally wet. In spring heavy and continued rains flooded meadows which, later, showed the effect of chinch-bug attack. Even at haying time while the bugs were young and, according to all accounts, easily killed by heavy rains, they persisted in multiplying and living despite the fact that rains were so frequent and severe that only a portion

of the hay could be gathered in a proper condition. This was the state of affairs on July 5 when the hay was cut, and on October 10 Doctor Lintner stated that owing to continued rains grass was still lying in the fields and could not be gathered, while fields of oats remained unharvested. In all of the reports given of this outbreak it was stated that the damage was first observed in August or September, and it is believed that this will hold good as applied to northeastern Ohio.

As has been stated, the females oviposit as a rule at or just below the surface of the ground, and the young make their way upward in order to secure food. In case of cultivated grains this mode of procedure is absolutely imperative, as the bases of the plants are at that time too tough and woody to offer sufficient food. But in the case of timothy the conditions are entirely different, as the bulb of this plant, situated just below the surface of the ground and convenient to the place of oviposition, furnishes an ample supply of food without making it necessary for the young to crawl upward in order to secure it. Then, too, the surface of the ground in cultivated fields is nearly or quite free of dead leaves and stems, there being little but the vertical-growing plants to afford protection from the weather. In timothy meadows the surface of the ground is usually covered to the depth of an inch or more with dead and decaying stubble and leaves, and the top of the ground itself is often more or less loose and mellow in the immediate proximity to the bulbs of the plants. It would appear that we might here have a partial solution of the problem of the vital effects of precipitation on the young bugs. Besides, for aught we know, the progeny of this quite short-winged form may be better able to withstand naturally the effect of drenching rains than that of the east-bound long-winged form. We must recollect that in the one case the progenitors have worked their way over hot, arid plains as well as cool, damp prairies, while in the other case the tide of migration lay between the more elevated lands and the sandy beaches of the seashore where there was always a more or less near proximity to the ocean, until the tide of migration left the seashore and drifted westward over New York and onward into northeastern Ohio. (See map, fig. 17.)

This influence of precipitation on the young chinch bugs while in the act of hatching, and that of temperature upon the adults in winter, some illustrations of which have been included under the subject of hibernation, are the only cases where meteorological conditions appear to have a direct effect on this species. As previously shown, the temperature effects are, largely at least, unfavorable for such adults as may happen to be more or less unprotected during the hibernating season. Upon this point it might be well to suggest that this protection,

which may be composed of leaves and dried grass, may be burned away in early winter and thus leave the insects without the expected protective covering, or this covering may be still further augmented by a mantle of snow, which, remaining for a more or less protracted period of time, counteracts the influences of temperature, and the latter then becomes a factor of secondary importance in the problem of life among chinch bugs. It is very doubtful if temperature is as vital in its effects as are the indirect influences of precipitation during the breeding season.

It has long been understood that the two species of entomogenous fungi, *Sporotrichum globuliferum* Speg. and *Entomophthora aphidis* Hoffm., both of which attack the chinch bug, require for their rapid development an atmosphere heavily charged with moisture, and that without this neither of these becomes sufficiently abundant to cause any serious mortality among the insect host, but this matter will receive attention in the discussion of these parasitic foes farther on.

INFLUENCE OF TEMPERATURE ON THE CHINCH BUG.

The writer would call attention here to a possible influence of temperature upon what he has termed the west-bound tide of migration. When the time arrives for the hibernating adults to leave their winter quarters and disperse over the fields prior to oviposition, if the weather should prove too severe they have but to remain in these quarters a while longer until more favorable weather. Thus, along the northern Atlantic coast the season is generally much later near the shore than it is a few miles inland, and Mr. Schwarz[a] has called attention to the influence which this phenomenon exerts upon the chinch bug. Now, this retardation amounts probably to about a month in spring, which would have a tendency to delay oviposition, especially among the short-winged females. If this were continued through a long period of time, consequent upon the slow movement of this tide of migration northward along the coast, it would hardly be surprising to find that this retarded activity in spring had become so characteristic as to be retained after this tide had swept to the westward, and resulted in the species being thus single brooded in the East, while it is double brooded in the east-bound tide of migration in the West. This effect of a long habitation along the shores of the northern Atlantic would be to some extent encouraged by the prolonged northern winter and the correspondingly shorter period during which the species could breed, and thus instead of the effects of the old environment becoming obliterated they might be continued, or, as in case of the fore-shortening of the wings, still further intensified. If the effect of this prolonged period

[a] Insect Life, Vol. VII, p. 422.

of hibernation has been to reduce the number of broods, then it will have to be considered as a natural check, in that to a certain extent it prevents excessive abundance by reducing the number of offspring. This would also account for the rather surprising immunity that has heretofore been enjoyed by the northeastern portion of the country from the ravages of this destructive species.

NATURAL ENEMIES.

It is possible that there are some reasons which might appear to justify the placing of fungous enemies of the chinch bug among the natural checks, as they no doubt do exert a more or less powerful influence in that direction, but it seems more convenient to include them among natural enemies, especially as one at least has come to be applied artificially to overcome the insect. The fact that the abundance and consequent influence of these fungous enemies is almost entirely dependent upon meteorological conditions is sufficient to place them in a secondary position, even though they may under favorable meteorological conditions act as natural checks. All, doubtless, have other host insects, and the two most important have been known to break out again and again spontaneously and destroy myriads of chinch bugs when the latter were present in excessive numbers. But this has taken place only in connection with the necessary precipitation; hence these fungi become natural enemies only under certain favorable weather conditions; and though their season of most potent effect is during the time when the chinch bug is developing from the egg to the adult, yet as shown by observation they may exert powerful and fatal effects among the adults, where these last have congregated together in masses.

PARASITIC FUNGI.

The two species of entomogenous fungi to which reference has just been made are *Entomophthora aphidis* Hoffman[a] and *Sporotrichum globuliferum* Speg.[b] both having probably been associated in destroying the chinch bug spontaneously in the fields, and doubtless were distributed to correspondents by Professor Snow and others to be artificially established in fields where there was an overabundance of chinch bugs. For this reason it is impossible to separate the effects of the two in the earlier literature, even the first observations of Dr. Henry Shimer[c] probably applying to their joint effect.

[a] Hoffman, in Fresenius's "Entomophthoreæ," p. 208, figs. 59–67.

[b] Spegazzini, "Fungi Argentini," II, p. 42.

[c] Proc. Acad. Nat. Sci. Phila., May, 1867.

Doctor Shimer, however, was the first to call attention to the widespread and fatal effects of fungous diseases among chinch bugs, and while his explanations therefor seem now crude and illogical, his observations were made with such care and accuracy that we have not yet had occasion to materially revise them. Under date of July 16, 1865, he makes this observation: "* * * I found many dying on the low creek bottom land from the effects of some disease, while they are yet in the larval state—a remarkable and rare phenomenon for insects thus in such a wholesale manner to be dying without attaining their maturity, and no insect enemy or other efficient cause to be observed capable of producing this important result." Again, under date of July 22: "On low grounds the chinch bugs are dead from the disease above alluded to, and the same disease is spreading to the hills and high prairies."

Under this date also he speaks of the very wet weather, and states that in a barley field the chinch bugs began to die at about the same time that they did on the low creek bottom, and that they rapidly met the same fate, so that few of them lived to find their way to a neighboring cornfield, while under date of August 8 he states that of those that migrated to the cornfields "very few are to be found remaining alive; but the ground around the base of the cornhills is almost literally covered with their mouldering, decomposing dead bodies. They are dead everywhere, not lying on the ground alone, but sticking to the blades and stalks of corn in great numbers, in all stages of development, larva, pupa, and imago."

"This disease among the chinch bugs was associated with the long-continued wet, cloudy, cool weather that prevailed during a greater portion of the period of their development. * * *"

These are precisely the conditions under which these fungi have been observed to prove the most fatal to the chinch bug during recent years, where their introduction among the host insects was accomplished by artificial means. Although Doctor Shimer probably never anticipated the artificial cultivation of his "disease," and the results which have since been obtained from its artificial dissemination in the fields, yet his careful and painstaking studies must ever be associated with the application of fungous diseases in the destruction of insects in America. It is certainly to be regretted that such practical entomologists as Mr. B. D. Walsh and Dr. C. V. Riley should have expressed themselves so discouragingly regarding Doctor Shimer's observations and conclusions, Doctor Riley, as late as 1870, even going so far as to ridicule the theory of disease being in any way responsible for the death of the chinch bugs observed by Doctor Shimer.[a]

[a] Second Report State Entomologist of Missouri, pp. 24–25, 1870.

It was not until 1879 that an entomologist came to the rescue of Doctor Shimer's theory of disease among chinch bugs. Dr. Cyrus Thomas, in Bulletin No. 5 of the United States Entomological Commission, 1879, page 24, stated that while Doctor Shimer's plague among chinch bugs was somewhat extraordinary, yet it was in accordance with facts that he had himself ascertained in reference to other insects, and in proof he cited a similar wholesale destruction of flies in southwestern Virginia and eastern Tennessee in the year 1849, and also a similar epidemic among grasshoppers in western Minnesota, Dakota, and northern Iowa in 1872. This position of Doctor Thomas in support of Doctor Shimer may be regarded as a second step in our advance in a knowledge of the influence of meteorological conditions on the chinch bug. It paved the way for further research in this direction.

FUNGOUS ENEMIES OF THE CHINCH BUG DETERMINED.

While the subject of epidemic and contagious diseases of insects was discussed to a greater or less extent among scientific men, there was a decided lack of actual experimentation, and none at all with the fungous parasites of the chinch bug until 1882 and 1883, when Prof. S. A. Forbes began what ultimately proved to be a long series of studies of the chinch bug and its natural enemies. At this time, 1882, Professor Forbes was more especially interested in the bacterial diseases of the chinch bug, and though he found, at Jacksonville, Ill., many specimens of dead chinch bugs embedded in a dense mat of white fungous threads, which sometimes almost hid the body and reminded him of the fatal disease previously reported by Doctor Shimer, yet except to secure from Prof. T. J. Burrill a determination of this fungus as belonging to the Entomophthora no progress was made in the study of this particular phase of the chinch-bug problem.[a]

In July, 1887, Professor Forbes found attacking the chinch bug in Clinton County, Ill., a second fungus, which he determined as belonging to the genus Botrytis, but this conclusion has since been revised and the species is now known as *Sporotrichum globuliferum* Speg. This discovery of a second species of entomogenous fungi and its separation from the Entomophthora comprises what may be justly termed a third step in the advancement of our knowledge of this problem. Professor Forbes, however, seems to have still been too deeply interested in his bacterial studies to pay any special attention to the other phases of his problem, further than to record the occurrence of his new Botrytis in various localities in Illinois, and in one instance on a beetle, *Parandra brunnea* (observed by Mr. John Marten, at Champaign), and, similarly, to note the occurrence of the still specifically undetermined Entomophthora.[b]

[a] Twelfth Report of the State Entomologist of Illinois, pp. 47–51, 1882.

[b] Sixteenth Report of the State Entomologist of Illinois, pp. 46–49, 1888.

The scene of action now changes from Illinois to Kansas, and to Prof. F. H. Snow belongs the credit of first applying the knowledge that had been gained up to that time (1889) by confining supposed healthy chinch bugs with others affected by either one or the other of the fungi, or possibly both Entomophthora and Sporotrichum, and using the bugs thus infected for the propagation, in the field, of the disease from which they had died.

As early as 1887–88 Professor Snow expressed, in the Sixth Biennial Report of the Kansas State Board of Agriculture, the opinion that "in the warfare of man against his insect foes a most valuable ally will be found in the bacterial and fungoid diseases which may be artificially introduced when nature fails to come to our aid," an opinion at that time largely based upon the investigations of Professor Forbes and his own observations of the chinch bug in Kansas, thus paving the way for the experiments of 1889. Professor Snow had now obtained a specific determination of the fungous disease as (*Empusa*) *Entomophthora aphidis* Hoffman, although there is some ground for the suspicion that *Sporotrichum globuliferum* was also present.

Entomophthora aphidis was already known to affect Hemiptera in Germany and the United States. Dr. Roland Thaxter[a] states that, as early as 1886, his attention had been called to the attacks of this fungus on aphides in the greenhouses at Cambridge, Mass., where it acted as a decided check, and later, in 1887, Dr. L. O. Howard had called his attention to great quantities of aphides dying with the same disease on clover near the Agricultural Department buildings in Washington, D. C.

FIELD AND LABORATORY EXPERIMENTS IN INDIANA.

On July 20, 1889, the writer, at that time a special agent of the Division of Entomology of the United States Department of Agriculture, stationed at Lafayette, Ind., received, through the kindness of Professor Snow, enough material with which to make some experiments, the chinch bug being at that time very abundant at Lafayette, and an exceptionally good opportunity thus being offered for experimentation. The results of these experiments were published in detail in Bulletin 22 (old series), United States Department of Agriculture, Division of Entomology (pp. 55–63), but as this was the first series of experiments carried out with a view of testing with exactness the precise effects of varying degrees of temperature and atmospheric moisture on the growth of the Entomophthora, and carefully following out the progress of the disease under varying meteor-

[a] Memoirs Boston Society of Natural History, Vol. IV, p. 176.

ological conditions, the matter is here republished in full, the bulletin in which it was originally included being now out of print.

These diseased bugs were placed under glass with living ones from the fields, the latter being provided with food and kept thus confined for fifty-three hours, when the major portion of them were placed on several hills of corn seriously infested by bugs, the remainder with the dried remains received from Professor Snow being scattered about over a small area of young wheat sown for experiment and also swarming with young chinch bugs. The hills of corn on which the bugs had been placed were isolated from others, equally badly infested, by narrow frames of boards placed on the ground and the upper edges covered with tar. This last precaution was taken in order to prevent communication with other hills, intended as checks on those used directly in the experiment. The area of young wheat over which infested bugs had been placed was not inclosed, but its limits carefully marked. Five days after, July 27, a single bug was found on one of the isolated hills of corn which had very evidently died from the effects of Entomophthora, and by the 30th enough others were found to show that the fungus had fully established itself and the barriers about the isolated hills were removed. On August 2 dead bugs covered with Entomophthora were found in considerable numbers about hills of corn 25 feet from where the original colonies had been placed and also throughout and even 55 feet beyond the area of young wheat over which dead and affected bugs had been distributed. Daily observations were now made, but the progress of the disease seemed to come to a standstill. From the 5th of August up to the 9th it was almost impossible to get sufficient material outside to enable me to carry on laboratory experiments. August 13 the spread of Entomophthora appeared to have taken on new life, and diseased bugs were becoming much more numerous. August 15 found diseased bugs 172 feet from any place where they had been previously observed. August 20 diseased bugs were very abundant over all of the area where disease had been distributed, and two days later examples were found a quarter of a mile from the starting point of the disease. Immediately after this, however, another halt was observed, both in the intensity of attack and rapidity with which it spread, due either to the dry weather or to the fact that the bugs had now all reached the adult stage and had become diffused over the country, no longer congregating together. From either one or the other, or both of these causes, I lost track of the Entomophthora and was not able to again find it in the fields. It seems proper to state here that chinch bugs were not at any time excessively abundant. The greatest numbers were in the exact localities where the disease was first distributed, the congregating at these places being brought about by the close proximity to a large number of small experimental plats of wheat, and when this was harvested the bugs collected *en masse* on the corn and young wheat. In connection with these facts, it is also interesting to note that from July 15 to August 31 there were ten days on which rain fell. The dates of these rains and the amount of precipitation is given below:

Date.	Precipitation.	Date.	Precipitation.
	Inches.		*Inches.*
July 17	0.02	July 29	0.78
19	1.25	30	.50
22	.20	Aug. 9	3.36
23	.04	13	.15
26	.13	14	.02

With a view of learning whether or not there was any difference as regards susceptibility to the attack of Entomophthora between bugs in different stages of development, a series of experiments was begun, as follows:

Young plants of *Setaria glauca* were transplanted to a box, and upon each plant was placed a dead bug covered with the fungus, and also healthy larvæ; larvæ just on the point of pupation; pupæ just prior to reaching the adult stage, and fully developed adults, each stage being placed on separate plants, and each covered with a small inverted glass vial designated by lettering. As checks, another series was prepared, like the first in every particular. The soil in the box was kept well moistened, and the plants remained fresh. This experiment was made on August 2, about the time when the attack outside began to diminish in intensity. The following are the results of examinations on the dates indicated, the original experiments being indicated by capitals and the checks by small letters, thus—A–a, adult; B–b, young larvæ; C–c, older larvæ; D–d, pupæ.

Date.	A.	a.	B.	b.	C.	c.	D.	d.
Aug. 5	Healthy ..	Healthy ..	Healthy ..	Healthy ..	1 dead....	Healthy .	1 dead ...	1 dead.
Aug. 6	1 dead	1 dead....	Healthy ..	Healthy ..	1 dead....	Healthy .	3 dead ...	1 dead.
Aug. 7	All dead..	3 dead....	3 dead....	1 dead....	3 dead....	1 dead ...	.....	5 dead.
Aug. 16	All dead..	All dead..	All dead..	All dead..	All dead..	All dead.	All dead.	All dead.

On the same day this experiment was begun a second was also commenced, like the first in every particular, except that the healthy bugs used in experimentation were exposed to fungus-infected individuals for only five hours and then placed under their respective glasses. As a result, on August 15, thirteen days after, none had died, thus strongly indicating that the Entomophthora did not exist generally in the fields, and that it could not be communicated during a period of five hours' exposure.

On August 7 a large number of healthy bugs were placed under glass, with a number which had recently died from Entomophthora, the moisture in the vessel being absorbed by calcium chloride. A check experiment was also commenced, where the material and the conditions were the same, except the humidity of the atmosphere, care being taken to have the latter as nearly saturated with moisture as possible. August 10 the original experiment was divided and a portion of the healthy bugs removed and placed in a damp environment, the remainder being kept under the original dry conditions. The results on August 22 were as follows: In the original experiment, where the healthy bugs had been continually in dry quarters, not a single bug had died from Entomophthora. Not only this, but none of those which had been removed after three days and placed in dry quarters had died, showing that the disease was not contracted and did not develop in healthy bugs, though kept exposed in a dry atmosphere for fifteen days, nor could it be originated by placing in a damp atmosphere for twelve days bugs which had been exposed to contagion for three days in dry quarters. The results with the check experiment were quite different. Within five days after being confined with the Entomophthora the healthy bugs began to die from effects of the disease, and in three days more every one had died from the same cause, their bodies being covered with spores.

Still another experiment was tried, which consisted in confining a large number of healthy bugs with others diseased in a damp environment, and when the fungus had destroyed a portion the remainder were divided and a part removed to dry quarters. The result was that while those left in damp confinement con-

tinued to die, none of those inclosed in dry environment were destroyed. As the fungus had by this time become distributed over the experiment farm so that I could not tell with certainty whether material from the fields was in a perfectly healthy condition or not, no further experiments were made in this direction.

From the foregoing it will be observed that the essential element in all of these experiments was an abundance of moisture, without which the Entomophthora could neither become established nor flourish after it had gained a footing. Again, the extent to which the disease will prove contagious will depend upon the number of bugs. Without great numbers massed together comparatively few would contract the disease. To sum up the matter, there is little hope for relief to the farmer from the influence of Entomophthora, except when chinch bugs are abundant and massed together in great numbers, and during a period of wet weather. I have succeeded in getting the fungus established at two widely located points in Indiana, and do not consider it at all difficult to introduce in localities where chinch bugs are abundant, provided the weather is favorable. But if it is ever utilized by the farmer, which seems to me to be at present a matter of considerable doubt, it will only be after the pest has become very abundant, during the time between the first larval and adult stages and in a wet time. After the Entomophthora has been introduced into a certain field it will become diffused only in proportion as the bugs travel about and healthy bugs come in contact with spores from those which have died from the disease. This will not be very great until the pupal stage is reached.

The larvæ of chinch bugs seem to in some way understand that while molting they will be well-nigh helpless, and hence hide themselves away in vast numbers in secluded places. Under such conditions the spores thrown from diseased bugs would reach a larger number of their fellows. I have found adults but recently molted affected by the Entomophthora. After the bugs acquire wings and scatter themselves over the country, the liability to contagion will be again reduced, unless in case of very severe invasions, where, from force of numbers, congregating on or about food plants becomes a necessity. Hence the introduction of the fungus among larvæ will at first proceed but slowly, and only in extreme cases and under favorable conditions can it be expected to proceed much more rapidly among adult bugs. In short, the only way that this fungoid disease seems capable of being employed in agriculture is by the establishment of some central propagating station to which farmers can apply and receive an abundant supply of infected bugs on short notice. By this means they could take advantage of a rainy period of a week or ten days, and, if they can contrive by sowing plats of millet and Hungarian to mass the bugs in certain localities about their fields, they might accomplish something toward warding off an invasion. But the possibility of overcoming an invasion after it is fully under way, as is almost sure to be the case during a dry season, it must be confessed is not very encouraging. My failure after repeated experiments to produce this Entomophthora in the vicinity of Lafayette without the importation of germs is decidedly against the theory that might be advanced that the northeastern portion of the State was kept free of destructive invasions by reason of this disease brought about by wet weather. There is as yet no reason to believe that the disease has ever existed in that section of the State.

The fungus entering into these experiments was determined as an Entomophthora by Dr. J. C. Arthur, and the probability is that it was *E. aphidis*, though it is possible that Sporotrichum was also present and remained unobserved.

FIRST FIELD APPLICATIONS OF FUNGOUS ENEMIES OF THE CHINCH BUG.

As has been stated, the credit for first confining healthy chinch bugs with those diseased and utilizing the individuals thus infected by transporting them to sections of the country supposedly free from the disease in order to create new areas of infection, belongs to Prof. F. H. Snow. During October, 1888, the year prior to that during which Professor Snow began his experiments, Prof. Otto Lugger, of Minnesota, collected a quantity of diseased chinch bugs at the experiment station at St. Anthony Park and distributed them to eighteen different localities in the southern part of the State where the pest was known to occur in destructive abundance. The diseased material was sent out in tin boxes by mail, and the contents of the boxes, on arrival at their destination, were simply thrown in any field where there was an abundance of chinch bugs. Later in the season the condition of affairs where these distributions had been made was such that "careful search in the majority of places failed to produce a single living specimen, while the traces of the disease were found everywhere." With a spirit of caution and exactness in every way most commendable on the part of Professor Lugger, he says: "The disease spread so rapidly that even corn growing near wheat fields crowded with chinch bugs was entirely protected, and no bugs had entered it in all the places visited by myself. But the writer is by no means satisfied that the disease was really introduced in this manner. Is it not possible that the disease was already there, unknown to anyone, and that the writer had simply reintroduced its germs? The reason for this belief is based upon the fact that too large an area was infested by the disease—too large to be readily accounted for by the short time in which the atmospheric conditions were apparently in its favor."[a]

In this case Professor Lugger states that both Entomophthora and Sporotrichum were present and the latter was sent by him to Professor Forbes, so there is the same confusion of the two fungi in this case that existed in the writer's experiments in Indiana, except that in the one case it was certain that Entomophthora was present, while in the other it was the Sporotrichum.

THE WORK OF PROFESSOR SNOW IN KANSAS.

Although Professor Snow had the experience and observations of Shimer, Forbes, and Lugger to aid him in his first efforts to apply the knowledge gained by these gentlemen, yet it must be said that it has been largely due to his untiring energy and perseverance that the use of these fungi has reached the present state of importance. It will hardly be saying too much if we state that his persistent un-

[a] University of Minnesota Experiment Sta., Bul. 4, Oct., 1888, pp. 40–41.

daunted labors, in the face of much skepticism and opposition, has won for him the admiration of his fellow-workers, even among those who were long in extreme doubt as to the success of his labor. He has done more than any other one person to call attention to the possibilities of practical benefits to be derived by farmers themselves; has done more to advertise the merits of these fungous diseases among the masses than anyone else, and, in fact, has made the "chinch-bug fungus" almost a household word over the entire United States.

It is therefore all the more to be lamented that he should have accepted and published in his several reports the unsubstantiated statements of farmers whose testimony on a matter of this nature is, as every entomologist knows, absolutely worthless unless accompanied by specimens. His own personal experience in this direction and in several States had long ago led the writer to disregard all reports relating to the efficiency or inefficiency of these fungous diseases among chinch bugs, when such came from the ordinary farmer without being accompanied by specimens for examination. The cast pupal skins of the chinch bug pass with nonentomologists very well for dead bugs, and if the former have been attacked by the ordinary white molds the deception, except to the eye of an expert, is complete.

There is probably not an entomologist who has distributed these fungous diseases among farmers who has not found just such conditions as did Professor Lugger in Minnesota, where it was impossible to determine whether these diseases had been introduced artificially or whether they were already present and had been overlooked. In the writer's experience, while receiving chinch bugs from different parts of Ohio to be infected with the disease, consignments have come to him with the insects dying and others dead and covered with Sporotrichum, showing that this was already present and that the very utmost that we could expect to accomplish would be to aid in locally spreading the contagion. Besides this, the writer has sent material to farmers sufficient to start the fungus in their fields, knowing perfectly well that it would be a considerable time before actual benefits could by any possibility be expected to materialize, and within a week received the astonishing information that the fungus was so perfectly successful that the bugs all disappeared within a few days after the application of the disease. There is little doubt that the distribution of upward of 7,000 boxes of these fungi to the farmers of Kansas has accomplished a vast amount of good, but beyond this it is impossible to go. Of Professor Snow's laboratory work or the labors of himself and assistants in the fields no criticisms can be made, and there will be occasion to quote from these in future pages of this bulletin.

Sporotrichum globuliferum, or at any rate the fungus which is now passing under that name, was first found by Professor Forbes to infest the chinch bug in Illinois in 1887, and its destructive effects observed in the fields in the autumn of 1888.

Since the last-mentioned date the writer distributed upward of 3,000 packages of this fungus to the farmers of Ohio during the outbreak of the chinch bug in the State in 1895, 1896, and 1897, and knows from personal observation and study that it is under certain favorable conditions a deadly foe of this species, that its use under these conditions is practicable, and that if its application can be made simultaneously with the commencement of the breeding season it will prove effectual. This statement is made for the reason that as late as 1895 Dr. M. C. Cook, in his popular work on entomogenous fungi, "Vegetable Wasps and Plant Worms" (p. 120), states that "no species of this genus is known to have occurred on living matter, as they are saprophytes pure and simple, and then, probably, only as the stroma or conidia of some fungus of higher organization, possibly the Sphæriacei." This statement was made in discussing *S. densum*, but on the following page (121), after dealing with *S. globuliferum*, he appends the following: "The remarks made under the previous species are applicable to this, which is not entitled to rank as a parasite, but rather as an accidental development upon one out of many forms of decaying animal matter."

OTHER INSECTS ATTACKED BY SPOROTRICHUM GLOBULIFERUM.

Spegazzini[a] described the species from Argentina as occurring on the dead bodies of beetles, notably Monocrepidius and *Naupactus xanthographus* Germ. Besides *Parandra brunnea* Fab., Professor Forbes has recorded this fungus on Lachnosterna and a number of other Coleoptera, and also on lepidopterous larvæ, as well as on the young of other insects, while the writer has infected, artificially, *Epicauta pennsylvanica* De G. and witnessed an instance of accidental infection of *Megilla maculata* De G., but failed to infect the harlequin cabbage bug (*Murgantia histrionica* Hahn) even when these were placed among dead and dying chinch bugs in the breeding cages. In both cases these beetles were almost entirely covered by the fungus after having to all appearances died from its effects. With respect to this matter one point is clear, either the determination of this fungus is incorrect or else Doctor Cook has made a very serious misstatement, which ought to be corrected. It is but just to state, however, that Professor Forbes, in his eighth report (p. 23), calls attention to the fact that it is closely allied to Botrytis, and would be placed by some botanists under that genus now.

[a] Spegazzini, Fungi Argentini, ii, p. 42.

FIRST ARTIFICIAL CULTIVATIONS OF SPOROTRICHUM GLOBULIFERUM.

In April, 1891, Dr. Roland Thaxter succeeded in cultivating *S. globuliferum* artificially on agar-agar, and a month later Professor Forbes made similar cultures on the mixture of corn meal and beef broth, this last being an exceedingly valuable discovery, as it revolutionized our method of distributing the fungus by securing chinch bugs to be kept for a time with those diseased and then sent out to be scattered over the fields—a cumbersome method which was never satisfactory. The writer's own work in Ohio was based on material obtained from Professor Forbes, and the first year he distributed infected chinch bugs, but after that he used the artificial base of beef broth and corn meal, finding the latter far more satisfactory to handle, and, so far as could be determined, equally effective.

RESULTS OF FIELD APPLICATIONS IN OHIO.

In regard to the writer's own experience, it is unnecessary to go into details, except to state that, under the most favorable laboratory conditions, he was able to kill apparently perfectly healthy chinch bugs within three days after bringing them in contact with the Sporotrichum. In the fields, during the season of 1895, though upward of 750 packages of diseased bugs were sent out to farmers, and some astonishing reports of results received therefrom, yet his own observations led him to believe that in many cases these were rather more imaginary than real. Over the areas where local showers occurred during the season of development of the first brood of young the effect was much more satisfactory. But in many cases the request for help came late, and soon after the fungus was applied the bugs scattered out over the fields, disappearing to the eyes of the ordinary farmer, who, of course, attributed all to the effect of the Sporotrichum. In 1896, however, meteorological conditions changed, and at last the writer had the good fortune to secure the very opportunity for which he had been waiting for years. All through April and up to the 10th of May in southern Ohio there was little rain, and even during the remainder of the latter month the light rains hardly sufficed to break the drought, so that there was a perfect breeding season for the chinch bug during the forepart of the breeding period. The result was that over some sections (see fig. 7) there were myriads of young bugs. Then the rains came on, and there were presented the two essential requisites for success with the fungus, viz, chinch bugs and wet weather.

Soon the demands for supplies of Sporotrichum began to pour in, and 1,200 packages were distributed within a few weeks, instructions being given to place the contents of the boxes where the chinch bugs

were massed in greatest abundance, giving preference to the lower and damper localities in the fields.

After the distribution had been finished, the sections where the outbreak of chinch bugs had been the most severe and where the larger portion of the Sporotrichum had been distributed were visited. There was certainly no mistaking the effect of the fungus. Going to the place in a field (generally a wheat field) where the fungus had been introduced, the track of the chinch bugs as they moved in any direction was in many cases almost literally paved with the dead bugs more or less enveloped in their winding sheets of white. Along ravines, dead furrows, or other depressions, the ground would be nearly white, the dead diminishing in numbers as the higher grounds were reached, though these were by no means free from corpses. In one instance the bugs had left a field of wheat at harvest, the Sporotrichum having been applied there before the movement began, and entered an adjoining cornfield. The way was marked with white, not only the surface of the ground, but on stirring up the mellow soil of the edge of the cornfield it was found to be literally full of dead chinch bugs to the depth of 2 or 3 inches, the white fungus-covered bodies strongly contrasting with the black color of the rich loam. Not only this, but under the sheaths of the leaves and on the leaves themselves hundreds of dead were to be found on the outer rows of corn, on the grass and weeds, and, indeed, almost everywhere. Millions of chinch bugs were certainly destroyed in this one field.

In other fields, where the number of bugs had been less, the dead were less numerous, and then they were more apt to be scattered over the leaves of the corn, as in such cases a diseased bug seems to be animated with a desire to crawl upward on any object which presents itself, just as a larva of the clover-leaf weevil, *Phytonomus punctatus* Fab., when attacked by *Entomophthora sphærosperma* (Fres.) will climb to the tip of a vertical blade of grass and coil itself around it, and, holding it in the grasp of death, remain in that position so strongly attached that the winds and rains fail to dislodge it until it has become disintegrated. In other localities, where no Sporotrichum had been distributed, the ravages had certainly been greater and the writer failed to find any indication of the presence of the fungus. So far as his observation extended, unless there were a sufficient number of chinch bugs massed to become injurious, the fungus had but little effect upon them. In other words, the massing appeared to be an essential requisite. Whether this was sufficient of itself, or whether the effect of massing was to reduce the vitality of the individual bug, and thus render it more susceptible to the spores of the fungus, it is impossible for the writer to decide; but he has long

suspected that the latter was the true solution of the problem. We know that most domestic animals or fowls thrive best and are the most vigorous when kept in small flocks, while among humans the maximum of health and minimum of disease is obtained where the individuals are scattered over a moderate area per capita and the atmosphere is dry and pure; low, damp, and ill-ventilated quarters, when overcrowded, being especially fatal, particularly to the young. The individual in perfect health and vigor may in one sense be said to be above and out of reach of disease, and before the two can be brought together there must be some interacting element that will bring the individual down to a point where he can be reached by the disease; that is, the disease can rise only to a certain plane and the victim needs to be first attacked by some element not necessarily fatal in itself, but sufficiently depressing to bring the individual down to where he can be grasped by the disease.

METEOROLOGICAL INFLUENCES FAVORING DEVELOPMENT OF FUNGOUS ENEMIES OF THE CHINCH BUG.

When human beings are overcrowded and some disease is introduced among them, everyone knows the effect of a low, damp locality under a high temperature and with both air and water more or less stagnant. Even the once healthy and vigorous are more or less reduced and enervated by their environment, and thus brought within the influence of the deadly disease. Again, if an individual is stricken and forsakes his miasmatic surroundings for those more salubrious, the disease may still overcome him, but seldom spreads to others, except such as come in actual contact with either himself or his belongings, while if not too much reduced before changing his habitation the chances are much more favorable for his recovery.

It seems to the writer that in this matter of metorological conditions and their relation to the effect of entomogenous fungi on the chinch bug we are really dealing with the same problem in a different field. The young chinch bug which has not yet come into possession of its full measure of strength, and the spent females, which have lost theirs, fall easiest as the prey to these fungi, while the fully developed bugs, endowed with health and vigor, appear to be to some extent immune to the attacks of these enemies, and if not massed in large bodies they seem still more likely to escape destruction. In the timothy meadows of northeastern Ohio an occasional dead adult has been found in late autumn, but the fungus had certainly not claimed many victims, though both the long and the short winged forms were present in considerable abundance, clustered about the roots of grass. With Forbes the writer believes that after becoming fully matured the chinch bug is, largely at least, beyond the reach of Sporotrichum. What is the

element that serves to enervate and reduce the older larvæ and pupæ, as well as many recently developed adults among them? Is there nothing that, not of itself fatal, so acts upon the system of the bugs that they are brought into a condition of susceptibility—a sort of "go-between," so to speak, but which demands atmospheric moisture before it will rise to an aggressive state?

A BACTERIAL ENEMY OF THE CHINCH BUG.

Forbes finds that the bacterium *Bacillus insectorum* Burrill is normal to the chinch bug and occurs always in the intestinal cœca, and the writer has often wondered if this were not the very reducing element. In a paper contributed to the "American Practitioner," September, 1891, he describes the effect of this bacteria on the cœca as completely destroying the secreting epithelium, the cells of which break down and disappear, leaving the delicate tubes filled with a vast mass of microbes with some small intermixture of droplets of fat and a little nondescript *débris*, the result of cellular decomposition. Now, it certainly seems to the writer that we may here have the very enervating element necessary and which, in order to become sufficiently aggressive to perform its functions perfectly, requires the very conditions afforded by frequent showers, without which it is comparatively helpless. We know very well that human beings are far more susceptible to disease when weakened by fatigue, dissipation, or other forms of exhaustion, and under such conditions succumb to disease when they would otherwise enjoy immunity therefrom. We will not, however, follow this further, but submit it as a problem well worthy of careful consideration and study. In his own experiments with *Sporotrichum globuliferum* the writer has found that under the most favorable conditions the fungus will attack even the youngest larvæ, while Forbes states that it will also attack the eggs, but in the fields it seemed generally most prevalent among the more advanced larvæ, pupæ, and newly developed adults, though much depends upon meteorological conditions and the abundance of chinch bugs, as well as the time during the breeding season when the fungus is doing its work. That is to say, there is a time at the beginning of the breeding season when there are only adults and young larvæ; later there will be larvæ of various ages, and, toward the last, few if any of these, but all will be either pupæ or adults. For some reason it seemed more difficult to get the Sporotrichum to work satisfactorily when the chinch bugs were beginning to breed than later on, the last of June and the early part of July. These facts are mentioned here to show that, judging by their effects, these fungi hold a secondary place.

THE PRACTICAL UTILITY OF FUNGOUS AND BACTERIAL ENEMIES IN FIGHTING THE CHINCH BUG.

Regarding the practicability of utilizing these entomogenous fungi in agriculture, there seems no reason to revise a statement made ten years ago, viz, that this can be done only in cases of excessive abundance and during wet weather, the basis for infection being provided by some central propagating station from which farmers can receive promptly an abundant supply. The writer believes that for himself he could manage to get considerable benefit from their use in destroying chinch bugs, provided he were located within the area of the frequent occurrence. This could be done only by watching the seasons carefully, and in case there should occur two years in succession wherein the breeding periods were covered by drought, then every preventive measure known should be adopted, notably the burning of leaves, dead grass, and other rubbish during winter or early spring, followed up by sowing small plats of early millet, Hungarian grass, or, better yet perhaps, spring wheat, in low damp places in the fields, with a view of attracting the females or in fact massing the bugs, and then freely applying the fungi in their midst. Whether the average farmer, with his somewhat crude ideas of entomology, can do this successfully or not is very uncertain. It is almost impossible to determine even a few weeks in advance whether a season is to be favorable or unfavorable to the development of the chinch bug, which would of itself cause occasional false alarm, and the precautionary measures rendered entirely unnecessary by a few timely and drenching rains just at the critical time. Before we can expect to be eminently successful in this matter, not only the farmer but also the entomologist and meteorologist have much to learn.

THE BOBWHITE OR QUAIL.

Chinch bugs have few important enemies among the birds of the northern United States. To what extent the coast birds feed upon them it is impossible to say, but inland the common quail or bobwhite (*Colinus virginianus*) is the only species that can be said to devour any considerable number. As this is one of our most highly prized game birds, it is slaughtered annually in tremendous numbers.

The following list will show the degree of protection offered the quail by legislative enactment in the States where the chinch bug is the most destructive. The close season for quail in the several States, during which killing is prohibited by law, is as follows:[a]

Maine, all the year.

New York, December 1 to November 1, except in some counties where it is from December 1 to October 16. In Rensselaer County it is from December 1 to October 1 and in Richmond County all the year until 1908.

[a] Farmers' Bulletin No. 265, pp. 13–25, 1906.

Pennsylvania, December 1 to November 1.
Ohio, December 5 to November 15.
Indiana, January 1 to November 10.
Illinois, December 20 to November 10.
Minnesota, December 1 to October 1.
Iowa, December 15 to November 1.
Missouri, January 1 to November 1.
Nebraska, December 1 to November 15.
Kansas, December 15 to November 15, with some exceptions where the close season extends to March 11, 1908.[a]
Oklahoma, February 1 to October 15.
Texas, February 1 to November 1.

The breeding season from latitude 38° northward to Canada begins in May, and continues through July and occasionally into September or even October. A young bird just from the nest was taken in Wayne County, Ohio, September 5, 1887.[b] There are probably two, and southward three, broods each season, and, while rather prolific, the quails are kept well reduced in numbers, at times to the verge of extermination over considerable sections of country. They are hunted incessantly and slaughtered without consideration, except for gain. Some also are killed by flying against electric wires, while entire coveys are sometimes smothered or frozen under the snow. As a result, the helpfulness of the quail against chinch bugs is greatly diminished.

OTHER BIRD ENEMIES OF THE CHINCH BUG.

Among the other bird enemies of the chinch bug are the prairie chicken, redwing blackbird, catbird, brown thrush, meadowlark, house wren, tree swallow, and horned lark, but there is little doubt that in seasons when the chinch bug is excessively abundant the comparatively few eaten by all of these birds is insufficient to reduce the numbers of the pest to any extent.

THE FROG.

Dr. Cyrus Thomas quotes Professor Ross and others as stating that the common frog is an enemy of the chinch bug. While this is probably true, it is nevertheless well known that comparatively few frogs frequent grain fields as a rule, and thus the benefit derived from their attacks is of too little importance to merit further notice.

---

[a] In Rawlins County, under restrictions, November 1 to January 1.

[b] A preliminary List of the Birds of Wayne County, Ohio, by Harry C. Oberholser. Bul. Ohio Agric. Exp. Sta., Tech. Ser., Vol. I, No. 4, p. 270.

INVERTEBRATE ENEMIES OF THE CHINCH BUG.

Of the invertebrate enemies the same may be said as of the frog. The writer has occasionally found a chinch bug containing a species of Mermis, "hair snake." Also occasionally ants may be seen dragging these bugs away, while lady-beetles have sometimes been found to devour them, as recorded by Walsh and Forbes. Perhaps the worst insect enemies of the chinch bug are to be found among its comparatively near relatives, the insidious flower bug, *Triphleps insidiosus* Say (*Anthocoris pseudo-chinche* of Fitch's Second Report) (fig. 15), and *Milyas cinctus* Fab. (fig. 16), the latter being reported by Doctor Thomas as the most efficient of the insect enemies of this pest, while Doctor Riley found that the former also attacked it. Professor Forbes ascertained by examinations of the contents of the stomach of a ground beetle, *Agonoderus pallipes* Fab., that one-fifth of the total food of this species was composed of chinch bugs. Doctors Shimer and Walsh both claim that lace-wing flies (*Chrysopa*) destroy chinch bugs, and they are doubtless correct. The writer has also very often found dead chinch bugs entangled in spider webs, though whether killed for food or by accident it has been impossible to determine. It will be seen, however, that the combined influence of all of the natural enemies of the chinch bug, parasitic fungi excepted, is far too weak to offer any material protection to the agriculturist against this pernicious enemy of his crops, with nothing to promise an improved condition of affairs in this direction in the future. There may sometimes appear hymenopterous parasites of the eggs, but we have as yet no proof of the existence of such in this country, and only suspect the possibility of such a phenomenon because other allied species have similar enemies, which destroy their eggs. In short, the immunity of the chinch bug from attacks of other organisms is so striking that it has attracted the attention of all entomologists who have made a study of the species, and all accept this as indicating that it is an exotic, not originally belonging to our insect fauna.

FIG. 15.—*Triphleps insidiosus* Fab. (From Riley.)

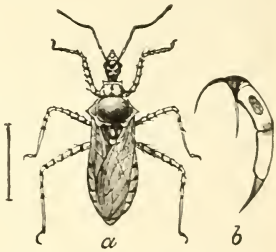


FIG. 16.—*Milyas cinctus* Fab. (From Riley.)

REMEDIAL AND PREVENTIVE MEASURES.

The list will include all remedial and preventive measures that have been found to possess the merit of reasonable efficiency and practicability. These may not all prove applicable in all localities or under

every variety of circumstance, and the farmer will often have to fit his protective measure to meet weather conditions, location of field and its surroundings, as well as the thousand and one other variations of a similar nature.

DESTRUCTION OF CHINCH BUGS WHILE IN HIBERNATION.

The first effort that may be made with a view to warding off an attack of chinch bugs is to destroy them in their winter quarters. This can be accomplished by burning all dried grass, leaves, or other rubbish during winter or early spring. Forbes (First Report, p. 37) and Marlatt (Insect Life, VII, p. 232) have cast some doubt upon the statements to the effect that the chinch bug hibernates to any great extent among dried grass, leaves, and rubbish, but the evidence is so overwhelmingly in favor of the assertions of nearly every entomologist who has studied the insect in its hibernation to the effect that it does select such places in which to pass the winter that there is hardly any use of raising the question at all. A good illustration of the fact that large numbers of chinch bugs may be in hiding in such places and escape detection is shown by the fact that a quantity of dried leaves from about a vineyard located on a narrow neck of land about a quarter of a mile from the Bay of Sandusky on the one side and about 1½ miles from the shore of Lake Erie on the opposite side were collected late in April and brought to our insectary and placed in a breeding cage. At the time of collecting the leaves only an occasional chinch bug was to be observed, but under the warm atmosphere of the insectary they began to stir themselves, and soon demonstrated that there had been a large number ensconced unseen among the dried and curled dead grape leaves. So it is with the matted grass along roadsides and fences, especially the Virginia worm rail-fence.

While it is not possible to find the hibernated chinch bugs by searching, yet if pieces of boards are laid down on the grass in early spring the bugs will collect on the under side and may be found there, or they may be discovered by the method of collecting known to entomologists as sifting. The burning of all such grass will destroy thousands of bugs in their winter quarters; but sometimes the matted bluegrass remains green in winter, or the weather is not sufficiently dry to enable the farmer to burn over such places. In such cases a flock of sheep, if given the freedom of the fields during winter and spring, will eat off all living vegetation and trample the ground with their small feet, so that not only is all covering for the bugs removed, but also the bugs are trampled to death. The ease with which the narrow strip of grass land along a post and wire fence can be kept free of matted grass and leaves, as compared with that along a hedge or rail fence, indicates that there may be

an entomological factor connected with the modern fence that has been overlooked, giving it, in this respect, an advantage over the more ancient form. Shocks of fodder corn left in the fields over winter certainly afford protection for many chinch bugs, as also will coarse stable manure spread on the fields before the chinch bugs have selected their place of hibernation in the fall. In short, the first protective measure to be carried out is a general cleaning up in winter or early spring either by burning or pasturing or both.

SOWING DECOY PLATS OF ATTRACTIVE GRAINS OR GRASSES IN EARLY SPRING.

Judging from the manner in which the wintered-over adults are attracted to hills of young corn, wheat fields, or plats of panic grass and foxtail, it has always seemed to the writer practicable to take advantage of this habit and sow small patches of millet, Hungarian grass, spring wheat, or even corn, early in the spring and thus bait the adults as they come forth from their places of hibernation. Their instincts will prompt them to seek out the places likely to afford the most desirable food supply for their progeny, and if an artificial supply can be offered them that will be more attractive than that furnished by nature, the bugs will certainly not overlook the fact, but will take advantage of it to congregate and deposit their eggs there, whereupon eggs, young, and adults can, a little later, be summarily dealt with by plowing both bugs and their food under and harrowing and rolling the ground to keep the former from crawling to the surface and escaping. The writer has thoroughly tested this method in a case where the bugs, young and old, had taken possession of a plat of neglected ground overrun with panic grass (*Panicum crus-galli*), which was mown and promptly removed and the ground plowed, harrowed, and rolled before the bugs could escape, thus burying them beneath several inches of soil out of which they were unable to make their way, and as a consequence they were almost totally annihilated, hardly 1 per cent making their escape to an adjoining cornfield.

DIFFICULTY OF REACHING CHINCH BUGS IN MEADOWS.

There is, however, some doubt in regard to the practicability of applying these measures in meadows. Meadow lands can be burned over with perfect safety to either the grass or clover, if done while the ground is frozen, but there is danger of injury if burned over in spring, and it is somewhat doubtful if the hibernating chinch bugs would be killed unless the surface of the ground was heated to a degree that the grass and clover plants would hardly be able to withstand.

Infested areas of meadow land could be plowed, it is true; but the work would have to be done very carefully, else the grass and stubble would be left to protrude above ground along each furrow and constitute so many ladders by which the chinch bugs could easily crawl out and make their escape. Where the ground will admit of subsoiling, or where a "jointer" plow can be used, this latter difficulty can be easily overcome. Usually, however, the chinch bug works too irregularly in a field to permit of plowing under infested areas without disfiguring it too much for practical purposes, especially in the case of meadows, unless it be where the bugs have migrated *en masse* from an adjoining field, when a narrow strip along the border can often be sacrificed to good advantage. In many instances the heroic use of the plow in turning under a few outer rows of corn would have saved as many acres from destruction. In the majority of cases it is the fault of the farmer himself that these measures are not effective, as he will seldom take the trouble to burn the dead leaves, grass, and trash about his premises at the proper time, and when there occurs an invasion of chinch bugs, instead of resorting to heroic and energetic measures to conquer them on a small area he usually hesitates and delays in order to determine whether or not the attack is to be a serious one, and by the time he has decided which it is to be, the matter has gone too far, and the chinch bugs have taken possession of his field. This is especially true in the West, where the bugs breed exclusively in the fields of wheat and remain unobserved until harvest, when they suddenly and without warning precipitate themselves upon the growing corn in adjacent fields. In fighting the chinch bug promptness of action is about as necessary as it is in fighting fire.

WATCHFULNESS NECESSARY DURING PROTRACTED PERIODS OF DROUGHT.

It has always appeared to the writer as though a little watchfulness on the part of farmers during periods of drought might enable them to determine whether or not chinch bugs were present in any considerable numbers in their fields, in time to interpose a strip of millet between the wheat and corn, to be utilized later as previously indicated. Instances have come under observation where, the wheat fields being overgrown with panic grass and meadow foxtail, the bugs transferred their attention to these as soon as the wheat was harvested, and a prompt plowing of the ground would have placed the depredators beyond the possibility of doing any serious injury. If the weather at the time is hot and dry, a mower may be run over the stubble fields or along the borders of them, cutting off grass, weeds, and stubble, as the case may be, leaving them to dry in the hot sun, when, in a few hours, they will burn sufficiently to roast all bugs

among them, and, while not destroying every individual, this will reduce their numbers to such an extent that they will be unable to work any serious injury.

In case the weather at the time should, on the contrary, be wet and rainy, so that it is impossible to mow and burn, the prompt distribution of the fungus Sporotrichum will prove of immense value; for in this case the more the bugs are massed over a limited area, the more fatal will be the effects of the fungus, and especially will this prove true if the land is low and inclined to be damp. This statement will also hold good with reference to meadow lands during the breeding season, though later the adults do not appear to succumb to the effects of the fungus nearly as readily, and the writer has found the fungus present in spring among masses of hibernating individuals, with little indication of its contagious nature, only an occasional individual being attacked.

UTILITY OF KEROSENE IN FIGHTING CHINCH BUGS.

In fighting the chinch bug there is at present no more useful substance than kerosene, either in the form of an emulsion or undiluted. From its penetrating nature, prompt action, and fatal effects on the chinch bug, even when applied as an emulsion, it becomes an inexpensive insecticide, while it has the further advantage of being an article of universal use in every farmhouse, and is therefore always at hand for immediate use. The emulsion has the further advantage of being capable of sufficient reduction in strength to prove fatal to insect life and yet not injure the vegetation upon which such may be depredating. Diluted and ready for use, the emulsion is prepared as follows: Dissolve one-half pound of hard soap in 1 gallon of water, preferably rain water, heated to the boiling point over a brisk fire, and pour this suds while still hot into 2 gallons of kerosene. Churn or otherwise agitate this mixture for a few minutes until it becomes of a cream-like consistency and, on cooling, will form a jelly-like mass which adheres to the surface of glass without oiliness. For each gallon of this emulsion use 15 gallons of water, mixing thoroughly. If applied to growing corn it will be best to use the emulsion either during the morning or evening, say before 8 a. m. or after 5 p. m., as at those times it will be less likely to affect the plants than if applied in the heat of the day.

Where an invasion of the chinch bug is in progress from a field of wheat to an adjoining field of corn, as an illustration, the marginal rows of corn can frequently be saved, even after the bugs have massed upon the plants, by spraying or sprinkling them freely with kerosene emulsion, being careful not to get much of it directly into the crown of the plants and using a sufficient quantity so that the emulsion will

run down the outside and reach such bugs as are about the base of the plants. This treatment will kill the bugs clustered upon the corn, and in case of those on the way to the field, while it will not keep them out, it will cause a halt in the invasion, and thus give the farmer an opportunity to put other measures in operation, one of which will include the use of kerosene in another manner. If a deep furrow is plowed along the edge of the field, running the land-side of the plow toward the field to be protected, the furrow will form a temporary barrier to the incoming hordes.

UTILITY OF DEEPLY PLOWED FURROWS SUPPLEMENTED BY THE USE OF KEROSENE EMULSION.

In dry weather the sides of this furrow can be made so steep and the soil so finely pulverized that when the chinch bugs attempt to crawl up out of the furrow they will continually roll back to the bottom, where they can be sprinkled with either kerosene alone or with the much less expensive emulsion, and killed. In case of showery weather, which prevents the sides of the furrow from remaining loose and dry, the bottom can be cleared out with a shovel, making it more smooth and the sides more perpendicular, thus rendering it so much easier to follow along the bottom than to attempt to climb the sides. If holes are dug across the bottom at distances of, say, 30 or 40 feet, the bugs will fall into them and can be still more easily disposed of by the use of kerosene. That both of these measures are thoroughly practicable the writer has ample personal experience in evidence, and knows that under most conditions that are likely to obtain, prompt and efficient application is all that is necessary. During a few days this work will demand the closest watching and application, but fields of grain can be protected thoroughly and effectually if these measures are faithfully carried out, and the expense of time and money will be found to be less than in almost any other plan that has been up to this time discovered. In his own experience, in no case has a field attacked by a migrating army of chinch bugs come under the writer's observation, but that might have been saved from very serious injury by the prompt use of either of these measures, though under some conditions the farmer might find it advantageous to apply some of the other methods of protection here given.

THE SURFACE AND COAL-TAR METHOD.

The objections made by farmers to the use of most forms of these barriers is that the finest pulverized soil soon becomes incrusted by even the slightest rainfall and the bugs then pass over it without difficulty, while barriers of boards are expensive.

It is feasible to eliminate both by simply smoothing off a path along the margin of an infested field where such a one adjoins the one to be protected. This can be done with a sharp hoe, and as the margins of wheat fields usually become compacted it is but little trouble to thus clear off a path a foot or more in width, smooth as a floor, with the surface almost as hard. In the midst of this path post holes are sunk as in the bottoms of furrows, and a train of coal tar is run between them, being so arranged that it will reach the post hole near the inner side opposite the field from which the bugs are migrating. In this way as the bugs reach the train of coal tar they will follow along until they reach the post hole, while those meeting with the post holes will usually divide and, following around it, join with the flow of bugs moving along the train of coal tar. The result is that they become congested in the acute angle where the coal-tar train is intercepted by the post holes. Those in the apex of this angle can not turn back, and thus are continually pushed into the post holes by those behind. As the bugs, varying from the red larvæ to the almost black pupæ, mass along the line of coal tar they have much the appearance of a reddish-brown stream running into the holes. From these holes there is no escape and here the bugs can be readily killed by sprinkling with kerosene. The slightest train of coal tar is sufficient to obstruct the passage of the bugs, and light rains will not affect its efficiency. In dry weather these trains of coal tar soon become covered over with dust and must be renewed; but in showery weather there is no dust, and if the coal tar is renewed daily or, at most, twice each day it will accomplish its work and nothing further will be needed than to kill the bugs that have collected in the post holes. This measure is inexpensive and can be promptly put into operation if the coal tar is at hand. The writer has been able in this way to effectively protect a field of corn surrounded on two sides by a wheat field literally overrun with chinch bugs at harvest and during a time when light showers were occurring, frequently several times each day.

THE RIDGE AND COAL-TAR METHOD.

Differing quite materially from the preceding are the various combinations of coal tar and ridges of earth, smoothed and packed along the apex, or, instead of the ridge of earth, 6-inch boards, such as are ordinarily used for fencing, placed on edge and the upper edge coated with tar. Forbes has reported excellent results from the application of a line of coal tar put directly upon the bare ground where the surface has been rendered compact by a recent fall of rain. Even in this series of protective measures kerosene can be used to great advantage. In the experiment recorded by Professor Forbes the coal tar was put upon the ground between a wheat field and a cornfield

from an ordinary garden sprinkling pot from which the sprinkler had been removed and the orifice of the spout reduced in size with a plug of wood until the tar came out in a stream about the size of the little finger and made a line on the surface of the ground about three-fourths of an inch in width. Post holes were sunk along the line from 10 to 20 feet apart on the side next to the wheat field, thus practically completing the barrier, and the chinch bugs being unable to cross the line of tar accumulated in the post holes in vast numbers, where they were killed; and those bugs that had already entered the cornfield before the barrier was constructed were prevented from spreading farther by tar lines between the rows of corn, the infested corn itself being cleared of bugs by the application of kerosene emulsion. The same writer states[a] that several farmers in Vermilion County, Ill., prepared for the coal-tar line by hitching a team to a heavy plank and running this, weighted down with three or four men, over the ground once or twice until a smooth, hard surface had thus been made to receive the tar. If the barrier was to be made in sod, a furrow was plowed and the bottom of this made smooth by dragging the plank along the bottom. In both cases post holes were sunk along the tar lines, and in these were placed cans or jars into which the bugs fell in myriads and were destroyed.

On one farm of 250 acres a coal-tar line 90 rods in length was renewed once each day and killed about 8 gallons of chinch bugs. In the case of another farmer there were 300 rods of tar lines with post holes, cans, etc., which resulted in destroying about 10 bushels of chinch bugs. A 6-gallon jarful was destroyed in less than half a day at one point on the line. In this last instance the lines of tar were renewed three times a day, but even then less than a barrel of tar was used. Still another farmer, with 120 rods of tar line, used about a third of a barrel of tar and did not lose a hill of corn; he caught chinch bugs by the bushel. In some of the cases cited the tar line was run in a zigzag course, the post holes being situated at the angles, and in others leader tar lines were run obliquely to the main tar line, one end terminating at the traphole, but both of these plans were afterwards regarded as unnecessary, a single straight line being entirely sufficient and less expensive. The numerous cases where these methods were put into execution with entire success and at small expense is the best possible proof of their practical utility. If a farmer is situated near town, where refuse tin cans are dumped in any locality where they can be got out of the way, he can select the larger of these, set them in the post holes and partly fill them with kerosene and water. The water being heavier than the kerosene will sink to the bottom, leaving a stratum of kerosene on the surface.

[a] Twentieth Report of State Entomologist of Illinois, p. 39, 1898.

The chinch bugs falling into this will be forced down by the weight of those coming after, and thus all will be passed through the kerosene into the water below. This will obviate the necessity of frequently emptying the cans or treating their contents. It may also be stated that where the post holes are quite deep and enlarged at the bottom the bugs falling into them will perish without further attention.

OTHER BARRIER METHODS.

Professor Snow, working in Kansas, followed a somewhat different method and one that, under certain conditions, might be found superior to that used by Professor Forbes, or the furrow and kerosene method applied by the writer in Ohio. This modification consists in throwing up a double furrow, known among farmers as "back furrowing," and thus forming a ridge, the top of which is smoothed and packed with a drag having a concave bottom of the form of the ridge to be made. If the bottom of this drag is covered with zinc, it will be found to keep bright and polished and by this means make a smoother ridge. The substances used were coal tar as it came from the gas works and crude petroleum as taken from the oil wells. The former is the more easily obtained, except in certain localities, and will probably be found the more practical, as it stands on the surface better and is not so readily washed away by rains. Both of these substances are, however, offensive to the bugs, and they will seldom attempt to cross them or even come close enough to touch them, but on approaching will turn and run along the ridge in the evident hope of finding a gap through which they can pass. Post holes were dug on the outside of the line, but close up to it, so that the bugs in passing along beside the tar line would crowd each other into them. Professor Snow suggests that it will be better to construct this barrier several weeks prior to its being needed, as then the tar line has but to be run along the ridge and the post holes dug, when the whole system is complete and the chinch bugs can be thus shut out from the first.[a]

With these barriers of either ridge or furrow and the use of coal tar or crude petroleum, supplemented by kerosene emulsion, a very large percentage of the injury from chinch bugs may be prevented, and, in fact, with a reasonable degree of watchfulness and prompt action, all injury from migrating hordes may be prevented. The use of tarred boards set on edge or slightly reclining might, under some circumstances, take the place of the ridge or furrow, but these cases will be exceptional, and the use of kerosene emulsion will probably

[a] Fifth annual Report of the Director of the Experimental Station of the University of Kansas, for the year 1895 (1896), pp. 45–47.

be found equally practicable here, as also will the post holes for collecting the chinch bugs. This method is merely cited in order to call attention to its possible use where the others are found impracticable. The plowing of furrows has been in vogue since the first writings of Le Baron and the second report of Doctor Fitch, and may be utilized in other ways than those previously mentioned. A heavy log dragged back and forth in this furrow will pulverize the soil in dry weather, and Forbes has recorded the fact that where this has a temperature of 110° to 116° F. it is fatal to the young bugs that fall into the furrow, even if they are not killed by the log. As 120° is not uncommon in an exposed furrow on a hot summer day, it will be observed that there may be cases where this method will be found very serviceable, and especially is this likely to prove true in a sandy soil with a southern exposure. In sections of the country where irrigation is practiced these furrows may be flooded and in this way rendered still more effective without the expenditure of either time or money to keep them in constant repair. Doctor Riley long ago laid considerable stress on this measure, believing it of much value, especially in the arid regions of the far West. The same writer advised the flooding of infested fields, wherever it could be done, for a day or so occasionally during the month of May. It is hardly probable, however, that this will often be found feasible except in rice fields, where it is sometimes practiced.

NECESSITY FOR PREVENTING CHINCH BUGS FROM BECOMING ESTABLISHED IN FIELDS OF WHEAT AND GRASS.

In the foregoing it will be observed that prevention of migration has been the chief end in view either by destroying the chinch bugs in their hibernating quarters, and thus preventing the spring migration to the breeding places, or by various traps and obstructions to prevent them from migrating from such places to others not already infested. The great problem remaining to be solved is to prevent their breeding in wheat fields at all. As has been shown, it is absolutely impossible, with our present inability to forecast the weather months in advance, to be able to foretell whether or not an outbreak of chinch bugs is likely to take place. There may be an abundance of bugs in the fall—enough to cause an outbreak over a wide section of country—and these may winter over in sufficient numbers to cause some injury in spring, yet a few timely, drenching rains will outbalance all of these factors, and our wisest prognostications fail of proving true. It is this very factor of uncertainty that renders unlikely the successful carrying out, over any large area of country, of any protective measures where, as in this case, the benefit to be derived will only be realized nearly a year afterwards, if at all. The average farmer,

when smarting under a heavy loss, will often take such long-range precautions as to sow belts of flax, hemp, clover, or buckwheat around his wheat field once; but if the chinch bugs do not appear, and he sees the useless investment of time, labor, and seed, he will be likely to conclude next year to take the risk and do nothing. For the present, then, we have no method whereby we can prevent the chinch bugs from taking up their abode in wheat fields or timothy meadows and raising their enormous families there, except to destroy the adults in their winter quarters.

The writer once tried to destroy the young in a wheat field by spraying with kerosene emulsion the small areas of whitening grain that indicated where the pests were massed in greatest abundance. The result was unsatisfactory, and it is very doubtful if it is possible to apply this measure with any degree of success, and we are forced to the conclusion that, for the present at least, we shall be obliged to rely upon the measures previously given. It therefore becomes of the utmost importance to clean up the roadsides, and along fences and patches of woodland, as well as any other places likely to afford protection for the hibernating chinch bugs. There are of course obstacles in the way of carrying out this plan generally over any large area of country, and especially in sections where the rail fence predominates. But as the country gets older it will be found that it is not chinch bugs alone that seek these places in which to pass the winter, but myriads of the other insect foes of the farmer as well, and that careful attention to the condition of roadsides, lanes, hedgerows, and waste places about the farms, during the season when insects seek out these places wherein to pass the winter, will pay well for the time expended in that direction. It may come about that some phase of the street-cleaning reform may invade the country, and it is certain that if such were to occur it would, in time, save the country enough to go far toward reducing the expense of securing good roads. In fact, the term "good roads" ought to include the proper care of the roadsides, as well as the grading and macadamizing of the roadbed itself.

There are at present so-called weed laws in many States, and, though more or less of a dead letter in most cases, these laws are steps in the proper direction. The time when insect pests will be looked upon in the eye of the law as so many public nuisances, and the harboring of them a corresponding crime, may be a long way off, but as it gradually draws nearer to us we shall come to learn that, after all, it is the rational view to take and will go far toward solving not only the chinch bug problem, but many others of a similar nature. So far as the chinch bug is concerned, when we burn over the waste lands and accumulated rubbish about our farms in autumn or winter, we are simply applying the same check that the dusky

savage did when he lighted the prairie fires, though unwittingly and for an entirely different purpose. In the timothy meadows of the northeastern portion of the country, where, for lack of wings fitted for locomotion, the chinch bug does not so largely migrate to the waste lands in autumn, the problem is somewhat different, and it will require some careful experiments to determine the exact effects of burning over the meadow lands in winter, both on the hibernating chinch bugs and on the grass roots. There can be little doubt, however, that a rapid rotation of crops, so as not to allow the short-winged form to become thoroughly established in a meadow, and the burning over of waste places, thus destroying such rubbish and débris as will serve to offer hibernating places for the long-winged form, will go far toward settling the chinch bug problem in grass lands.

As previously stated, the chief drawback in putting preventive measures in force is in the difficulty of foretelling an invasion. In northeastern Ohio in 1897 hundreds of acres of timothy meadow were destroyed after the hay crop had been removed, but so late that the farmers did not suspect the true condition of their meadows until the spring of 1898, when the young grass failed to put forth and an examination revealed the fact that the roots had been killed, the abundance of chinch bugs pointing unerringly to the cause of the trouble, though in many cases a heavy crop of hay had been removed the previous year where now the ground was entirely bare. While in the case just cited a previous knowledge of the presence of chinch bugs in these meadows might not have enabled the owners to have saved them in the fall of 1897, yet the fall plowing of the land, possibly early enough to have sown the ground to fall wheat, would have buried the majority of the bugs so deeply in the soil as to have killed vast numbers of them and thus prevented their migrating to other lands in the spring of 1898. A rotation of crops that would have included grass for not to exceed two successive years, followed by wheat, would have amounted to precisely the same remedial measure as the one suggested.

A case in northeastern Ohio has come to the writer's notice where an infested timothy meadow was plowed late in the fall of 1897. Late in April of 1898 this ground was cultivated, rolled, and harrowed several times and most carefully and completely prepared for corn, which was planted, but with the result that a portion of the field was attacked and destroyed by chinch bugs, largely of the brachypterous or short-winged form. An examination about June 10 revealed the bugs in considerable numbers about the still remaining plants, but scattered over the field were more or less numerous clumps of timothy, in some cases apparently having been killed by the chinch bugs, while in others these were literally swarming about the dying but still

green clumps of grass, thus showing that the former had either not been buried by the plowing and cultivation of the ground, or else the grass had not been thoroughly covered, and thus ladders had been left whereby they were enabled to climb to the surface.

SUMMARY OF REMEDIAL AND PREVENTIVE MEASURES.

In summing up the matter of remedial and preventive measures for the control of the chinch bug, it may be stated that the insects can be destroyed in their places of hibernation by the use of fire. They can, under favorable meteorological conditions, be destroyed in the fields, if present in sufficient abundance during the breeding season, by the use of the fungus *Sporotrichum globuliferum*, if promptly and carefully applied. They can be destroyed while in the act of migrating from one field to another by tarred barriers or deep furrows supplemented by post holes, and by being buried under the surface of the ground with the plow and harrow; or the latter method can be applied after the bugs have been massed upon plats of some kind of vegetation for which the bugs are known to have a special fondness, which decoys should be so arranged as to either attract the females and induce them to oviposit therein, or they should be arranged with the idea of intercepting an invasion from wheat fields into cornfields. When these decoys have been turned under with a plow and the surface immediately smoothed and packed by harrow and roller, the bugs will be destroyed. While in the cornfields they can be destroyed on the plants by the application of kerosene emulsion. Without vigilance and prompt action, however, only indifferent results are to be expected from any of these measures.

PROBABLE ORIGIN AND DIFFUSION OF THE CHINCH BUG.

For the farmer engaged in attempts to check the ravages of the insect in his fields the question of origin, or how it came to reach him, will at the time have little interest for him. It will suffice that it is present in overwhelming numbers, and what he will most desire will be to learn how to rid his premises of its most unwelcome presence in the most summary manner possible.

If, however, the farmer happens to be a thoughtful and observing man he will sometimes wonder how it is that, except in Virginia and the Carolinas, a person need not be very aged in order to remember a time when the chinch bug was an unknown factor in his profession, with a possible value far too small to merit consideration. If he happens to reside in northeastern Ohio or in some portions of New York, and has spent some time in Illinois, Iowa, Kansas, or Minnesota, he will probably marvel at the striking difference in appearance

between many of the chinch bugs of his own locality and those found in any of the last-mentioned States, and will probably be able to satisfy himself of their identity only by the similarity of their vile odor. Again, he will probably be equally at a loss to understand why it is that his own timothy meadows are overrun by these pestiferous insects and destroyed, while in other localities, perhaps less than 100 miles away, similar meadows are left untouched, the injury there being confined to the wheat and corn fields.

If wondering leads to questioning, as it often does among the constantly increasing number of educated and up-to-date farmers, it will not satisfy him to receive an evasive or obscure reply to his query as to why such differences exist, for if he can not get a clear explanation he will want ideas, theories, or possibilities. He wants the best explanation possible to give until some one finds out a better one, realizing that had mankind been perfectly satisfied with the knowledge that a stroke of lightning would split a tree or destroy human life, and had stubbornly refused to listen to possibilities or to anything but facts, we would not now be able to understand and utilize electricity in the many ways that we do at the present time. Such men understand perfectly that the solution of most problems in natural science must of necessity commence with theories which must be patiently tested and adopted or rejected as the results demand, while the scientific man knows that the solution of one problem often opens up the way for the solution of another, the last not infrequently having an entirely different application from the first.

The science of applied entomology is growing rapidly and becoming both broader and deeper, and it is not enough simply to tell the husbandman what an insect is and how to kill it. He must have something along with that information to set his own mind to thinking, to work out problems or improve upon the solutions already given him, otherwise it is much like giving money to a professional beggar. If we can not give facts based upon demonstrations, then give the best explanation possible, even though it be a theory which is only expected to stand until some one does better. It is for the thoughtful, progressive farmer, as well as the student of geographical distribution, that this possible solution of the problem of the chinch bug has been prepared, and while the full practical value of the ideas advanced has yet to be demonstrated, this of itself can not be urged as sufficient grounds for not sending it forth for study and consideration.

Thanks to the careful observations of Professor Sajö, on the European species of chinch bug, *Blissus doria*, it is now for the first time possible to compare the habits of this species with our own.

INDICATIONS OF A PROBABLE DISTANT ORIGIN AND LATER DIFFUSION.

In the United States our chinch bug, *Blissus leucopterus*, has a number of peculiar characteristics, which, while having an economic interest, also point to a probable previous condition differing somewhat from the present, and not in all cases tending toward its present numerical strength. On the other hand, we find that it is now following some probably ancient habits which do not appear to be of any special benefit, but rather the reverse.

In the first place, over its area of greatest destruction, it appears to prefer level tracts of country where the damp conditions consequent upon frequent rainfalls remain the longest, and in the second place, the period of spring oviposition is for the most part included within that during which the spring rains of the United States usually occur—that is to say, throughout the great grain belt, east of the Rocky Mountains, April and May are not normally months of severe drought, and it is during these two months that the larger portion of the eggs are deposited. As in the reverse of this, however, the period of fall oviposition, August and September, is far more likely to be favored by a lack of precipitation. These conditions do not always obtain, and it is because of the fluctuations that the insect is able to reach its maximum in point of numbers.

Another factor which plays quite an important part in reducing the number of adults maturing during unfavorable seasons may be found in the almost universally gregarious habits of the young, thereby rendering the ravages of fungous diseases the more universal and fatal. In all of these peculiar characteristics as well as in some anatomical features, it would seem as if we had a series of guide posts, so to speak, which indicate more or less clearly the ancient home of the species, and at least throw some light on its origin and diffusion.

UNIQUE APPEARANCE AND GREGARIOUS HABIT.

Mr. E. A. Schwarz [a] some time ago called attention to "the unique appearance of the full-grown chinch bug, with its white wings and chalky-white pubescence," which, he declared, "forcibly indicates that the insect is either a psammophilous or a maritime species," and expressed the opinion that its geographical distribution fully bears out the theory that it belongs to the latter class. The same author states that the species has the habit of clustering about the roots of tufts of grass along the Atlantic coast, from Florida to Atlantic City, N. J., and Mr. W. H. Harrington [b] observed it to have the same habit along the seashore at Sydney, Cape Breton, in 1884. The late Dr.

[a] Insect Life, Vol. VII, p. 420.
[b] Can. Ent., Vol. XXVI, p. 218.

J. C. Neal, while at Stillwater, Okla., wrote me that he had observed the species to have the same habit in that Territory, miles from any human habitation. Dr. Asa Fitch[a] found them swarming amidst extensive prairies in Illinois, in 1854, while more recently Mr. C. L. Marlatt has witnessed the same phenomenon in Kansas.[b] In short, this gregarious habit seems to be most tenaciously adhered to wherever these insects are found in any numbers. When migrating from one field to another, after crossing a roadway or plowed field they will at once flock together on a few plants along the margin of the, to them, new field instead of scattering about, two or three to a plant. It may also be added that Mr. Koebele found the species in large numbers along the seashore not far from San Francisco, Cal., in the first, second, and third stages of development, on a species of grass growing along the coast.

It has not, so far as is known to the writer, been observed in similar places along the shores of the Great Lakes, though search has been made for it there, but it occurs in destructive abundance in timothy meadows inland in northern and northeastern Ohio 25 to 75 miles distant, most generally clustering about the roots of grass—which, by the way, is about the only vegetation attacked—as the species is described as doing along the seacoasts. It may also be stated that it seems to hibernate there precisely as observed by Mr. Marlatt in Kansas; Doctor Neal in Oklahoma; Mr. Schwarz in Virgina in the vicinity of Fortress Monroe, and as the earlier observations of Doctor Fitch in Illinois would imply. Thus we find this habit of clustering upon the plants attacked to be a constant one, and where the natural grass vegetation has not been displaced by farm crops, thus leaving the ground more or less bare during winter, the chinch bugs continue to hibernate there. With these two characteristic habits generally followed over the great area inhabited by the species in North America, we may add a third possible factor in the problem of origin and diffusion of the species which, though an anatomical dimorphism, may be discussed as likely to throw considerable light upon the probable ancient habitat of the insect.

OCCURRENCE OF THE LONG AND SHORT WINGED FORMS AND THEIR DISTRIBUTION.

The occurrence of both the long and short winged forms, intermixed along our seacoasts and in the northeastern section of the country, but not elsewhere, shows very plainly that this dimorphism is not due to the temperature of any particular locality, but must be regarded as having been brought about by disuse of the wings

[a] Second Report, Insects of New York, p. 283.

[b] Insect Life, Vol. VII, pp. 232–234.

for a considerable period of time, thus indicating a seashore habit on the one side, while the total lack of the short-winged form elsewhere indicated otherwise.

In a paper presented before the Entomological Society of Washington,[a] "On the insects found on *Uniola paniculata* in southeastern Florida," by Mr. E. A. Schwarz, the author stated that *Blissus leucopterus* occurred in large numbers on the upper part of the plant, the imagos and larger young among the ears and the smaller individuals between the upper blades. Mr. Schwarz attributes this habit to the tough woody nature of the storm-beaten plant nearer the ground, thereby driving the insects to the more tender though more exposed portion of the plant. In connection with this statement the writer tells us that the insect occurs in that southern latitude only in the short-winged form, and that in the examination of thousands of specimens from that region he had never found a single long-winged specimen. Under date of May 4, 1896, Mr. W. H. Harrington wrote of this species as follows: "In September, 1890, I found it at Aulac, almost on the border between New Brunswick and Nova Scotia. It seemed not uncommon and occurred under stones, about the roots of grass, in a pasture adjoining the marsh where I found *Diabrotica longicornis*, the pasture being on the upland skirting the marsh. Both the long and short winged condition occurred, as in Cape Breton."[b] Dr. A. S. Packard communicated to Dr. J. A. Lintner the following extract from his diary: "June 17, 1871, at Salem, Mass., chinch bugs with wing covers extending over the basal third of the abdomen, seen in copula, end to end.[c] In the serious outbreak of this insect in the timothy meadows of northern New York, in 1882 and 1883, about 20 per cent of the bugs were of this short-winged form."[d]

Although Dr. Asa Fitch, as early as 1855, refers to this form along with nine others, he does not give the source from which he obtained specimens, but just previous to this he says (p. 287) that he had met with but three specimens from his own State, and these were found on willow in the spring of 1847.[e] Had any of these been of the short-winged form he would have been very likely to have mentioned the fact. Mr. E. P. Van Duzee[f] states that he had known of the occurrence of the species in western New York as early as 1874, and had also found it at Ridgeway and Muskoka, Ontario. Ordinarily the short-winged form predominates, but in hot, dry summers the chinch

[a] Proc. Ent. Soc. Washington, Vol. I, p. 104. Read Nov. 3, 1887.
[b] Canadian Entomologist, Vol. XIV, p. 218.
[c] Lintner's Second Report, State Entomologist of New York, p. 164.
[d] Second Report, State Entomologist of New York, p. 156.
[e] Second Report on Noxious Insects of New York, p. 291.
[f] Canadian Entomologist, Vol. XVII, pp. 209–210, 1886.

bugs mostly acquire fully developed wings. He had never found the species in grain fields of any sort, but always in grass lands, generally in timothy or clover, but sometimes in wild grasses. Of eleven specimens collected from under the bark of an old log by Mr. J. Pettit, of Grimsby, Ontario, in 1866, and sent to Mr. B. D. Walsh for determination, all were of the short-winged form.[a] It was these specimens that doubtless led Doctor Riley[b] to call attention to the fact that in Europe there are many genera of half-winged bugs which occur in two distinct or "dimorphous" forms with no intermediate grades between the two, viz, a short-winged or sometimes a completely wingless type and a long-winged type. Frequently the two occur together and copulate promiscuously, while sometimes the long-winged type occurs in particular seasons, especially in very hot seasons, while more rarely the short-winged type occurs in a different locality from the long-winged type, and usually in that case in a more northern locality. In northeastern Ohio the species occurs during some years in great abundance and very largely at least on timothy. Here the short-winged form is very largely in the majority, and in the spring of 1897, of 1,900 specimens collected indiscriminately, only about 400 were of the long-winged type.

In northern Indiana, where the insect occurs but rarely, this short-winged type does not predominate; but aside from these two localities, with an acquaintance with this species running over forty years, chiefly in Indiana and Illinois, the writer has never met with the short-winged type among millions of adults. If this short-winged type occurs elsewhere to the westward, except along the Pacific coast, where both forms have been collected by Koebele and others, it has not been found by entomologists, even to the northward as far as Minnesota, Winnipeg, and Manitoba, while to the eastward of this Mr. Van Duzee collected the brachypterous form on Muskoka River, Ontario, near the lake of that name.[c] On comparing specimens from New York with a large series from Kansas, the former were found to be quite uniformly more robust, with longer hairs on the pronotum.[d]

It would seem that here we have evidence of two distinct tides of migration, the one sweeping north and eastward, while the other has mainly been to the north and westward, meeting the former in northeastern Ohio and northern Indiana, and possibly somewhere farther to the north in British America. The two, besides differing in the length of the wings, are sufficiently unlike in appearance to attract the attention of students of Hemiptera.

[a] Practical Entomologist, Vol. II, p. 23.

[b] Second Report on the Insects of Missouri, p. 22, 1870.

[c] Can. Ent., Vol. XXI, p. 3, 1889.

[d] Loc. cit., Vol. XVIII, p. 209.

RELATION OF THE INLAND AND SEACOAST SHORT-WINGED FORMS.

It is possible that the short-winged form of chinch bug found in Ohio is precisely the same form as that found along the seacoasts, but it seems to the writer that the inland form originating from this maritime short-winged element, instead of acquiring wings of normal length as it drifted away from the coast, has really moved in the other direction, and the wings have become still further aborted.

It will be observed by the illustrations given of both the inland and maritime short-winged forms (see figs. 3 and 4) that in some of the former the wings have become so aborted as to become almost invisible, while in the latter, though the wings are very much shortened, they are nevertheless very clearly to be observed. It would seem, then, that we might reasonably presume that the species was originally long-winged, but, living along the seashore, the winged individuals have either flown each year inland or else been blown into the sea to such an extent that a short-winged form has thus been evolved which was unable to migrate and not easily blown into the sea. In pushing inland while the country was still inhabited by the aborigines another source of destruction would confront these insects in the annual recurrence of fires whereby vast areas of country were burned over in autumn, winter, or early spring, and these must have destroyed very many of the hibernating insects, while such individuals as migrated to sections not so burned over would escape destruction.

PROBABLE COURSE OF DIFFUSION.

Let us suppose that the species originally worked its way northward from South America, or even Panama, along the lowlands between the more mountainous interior and the Gulf of Mexico until it reached Texas with its vast areas of level country extending not only across the State itself, but northward into British America, and, generally speaking, with the exception of the Ozark Mountains in Missouri and Arkansas, eastward to the Appalachian system extending from Cape Gaspé, Quebec, Canada, to northern Alabama. This area is more or less covered with a grass flora that affords ample food for these insects, and it would seem that there was here offered every incentive to migration broadly to the northward and eastward, and at the same time there would be the Gulf coast along which those individuals which either could not or did not migrate inland could make their way as had their progenitors along the coast in Mexico. (See fig. 17.)

Now, it would appear as though the short-winged individuals, if there were any such, would remain along the coast, while the long-winged individuals would, at least more or less of them, migrate inland, and at least some of these, but far more of those unable to fly,

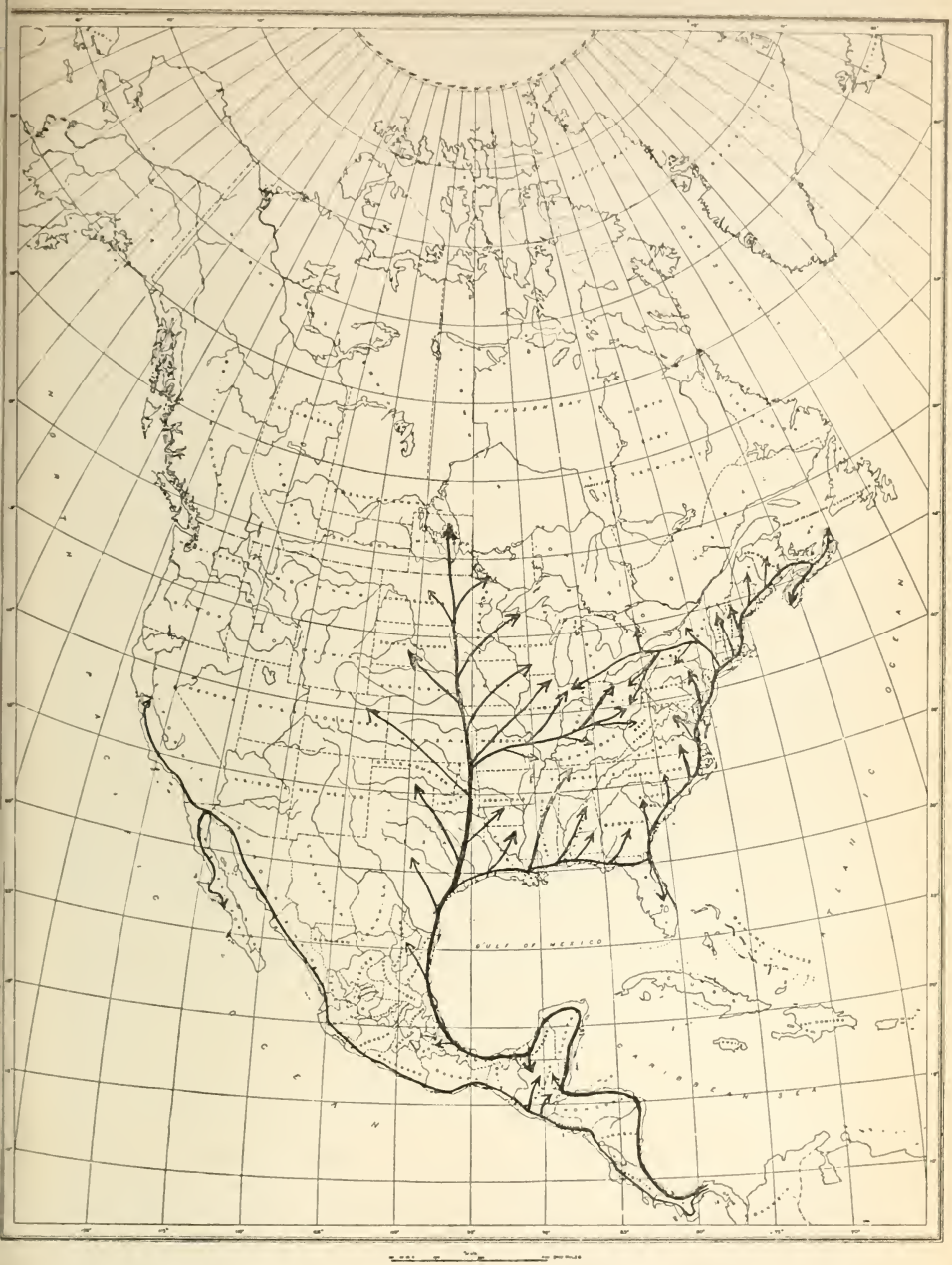


FIG. 17.—Map showing probable course of diffusion of chinch bug over North America. (Author's illustration.)

would be annually destroyed by the prairie fires, thus eliminating whatever tendency there might be to perpetuate the brachypterous forms, and develop a fully winged more or less nomadic race which, as it slowly advanced inland, lost all vestige of its brachypterous ancestry, if such had existed.[a]

On the other hand, we might expect the shore-inhabiting individuals to continue in their progress along the coast, the winged individuals continually migrating inland, leaving a mixture of the two forms to push forward to the east coast of Florida—where as late as 1906 it attacked grass on lawns about Palm Beach—and northward along the Atlantic to Cape Breton. As soon as this migration had passed the southern terminus of the Allegheny Mountains the inland spread would, very largely at least, be restricted to the area lying between the eastern slope of these mountains and the coast, thus leaving the whole area to the west to be occupied by the northward tide of migration instead of that from the east. East of the Mississippi River and south of the Ohio River the country is more heavily timbered and the prairies are lacking, so that forest fires would here take the place of prairie fires; but in the Southern States the woods are composed more largely of pine, and Doctor Lugger, in Minnesota, found that the chinch bug did not invade the region on which only pine and other Coniferæ grew, but that the more southern counties of his State, which are more or less wooded with deciduous trees, were invaded. He also called attention to the fact that before the country was settled by the whites these timbered lands were burned over frequently, probably annually, but now the wooded areas are confined to small tracts interspersed among the farms, and as these are not annually burned over they afford suitable shelters for the chinch bug during winter, and the grain fields of the farmer afford ample food during the summer, while on the prairies which are burned over such is not the case.[b]

Along the eastern coast the chinch bug has never been especially destructive to the wheat crop north of North Carolina, where, according to Doctor Fitch,[c] the earliest depredations occurred in 1783, while Webster[d] states that it threatened total destruction to the grain in 1785; but since that time the ravages have not been nearly as severe as farther west in the Mississippi River Valley. In 1899, 1900, 1901,

[a] Prof. H. A. Morgan, then entomologist of the State Experiment Station of Louisiana, writing under date of May 30, 1898, states that he has never found the brachypterous form of chinch bug in that State, and the writer did not observe a single individual of these among the many macropterous specimens taken by himself in that State.

[b] First Annual Report of the Entomologist of the State Experiment Station of the University of Minnesota, 1895, p. 26.

[c] Second Report on Noxious, Beneficial, and other Insects of New York, p. 278.

[d] Webster on Pestilence, Vol. I, p. 279.

and 1902 this maritime form destroyed the timothy in the vicinity of Reidsville, N. C. This is on the southern border of timothy culture along the Atlantic coast, and some years ago an attempt was made to grow timothy in that section. The grass did very well until the above-mentioned attack occurred, and by 1905 there was but little remaining.[a] Strangely, too, nowhere along the Atlantic coast do we find the short-winged individuals far inland until we reach New York and the New England States, and what is equally perplexing they do not there attack grain, but grass, whereas to the southward, except near the seacoast, it is the grain fields that are devastated by the long-winged form. In other words, throughout New England, New York, northeastern Ohio, northern Indiana, and the Dominion of Canada we have both the long and short winged individuals occurring together, but depredating almost or quite exclusively upon timothy (*Phleum pratense*).

In Bulletin 17, old series, Division of Entomology, U. S. Department of Agriculture, Dr. L. O. Howard, the author, stated that in 1886 a timothy meadow located near Wakeman, Huron County, Ohio, was considerably injured by chinch bugs. Since that time the species has never been reported from that section of the State, and the writer has found that depredations of that particular character are only committed by the more or less brachypterous race. This has been supposed to be largely confined to the northeastern portion of the State, though there seems to be no good reason why it should not appear in northwestern Ohio also. Owing to these facts this single occurrence in meadows, recorded by Doctor Howard, formerly puzzled the writer greatly.

During the fall of 1898 there came reports of very serious destruction of meadows in Huron and Lorain counties, which lie contiguous to each other, the cause being attributed to the dry, hot weather. But an examination of the meteorological records for that section revealed the fact that there had been no weather condition sufficiently severe to affect timothy meadows in that way. A survey of the affected meadows during early spring of 1899 revealed the presence of great numbers of brachypterous chinch bugs hibernating in these meadows, and the problem was solved. The species had doubtless been doing more or less injury since 1886, entirely unknown to the farmer or anyone else, thus showing the extent to which its secluded life in meadows protects it from observation. This section of the State since 1886 has been more largely devoted to dairying, and the meadows are not as rapidly rotated with other crops as when the cereals were grown more extensively.

[a] Extract from correspondence of Prof. Franklin Sherman, jr., State entomologist.

In Ohio, which appears to be the frontier of destructive abundance, the line separating the habitat of the combined forms and that of the macropterous form, exclusively, indistinctly marks the line of separation between the most serious depredations and almost total immunity of attack on timothy meadows by chinch bugs. To the west and south of this a short-winged adult chinch bug is rarely seen, timothy meadows are seldom attacked, and then only where fields of small grain or corn are not in easy reach; as, for illustration, where the insect happens to breed in a wheat field surrounded by timothy, and, when the grain is harvested, there is no other recourse left it but to attack the grass. In the opposite direction from our line, however, the conditions are quite the reverse. Here, while fields of wheat are occasionally badly injured, thousands of acres of timothy meadow have been entirely killed out from its attack.

The area of destructive infestation of timothy meadows seems to extend on the east in Ohio from Lake Erie to the Ohio River at the northernmost point of West Virginia, and on the west, in the vicinity of Sandusky, it extends only 25 or 30 miles from the lake shore. In limited numbers the area of distribution extends westward, probably narrowing gradually, around the lower end of Lake Michigan into northern Illinois, where it seems to be on the increase, though still far from common. As will be shown further on, this form is not likely to become destructive where timothy is grown in rotation with other farm crops.

So far as it is possible to determine, there are a considerable number of winged adults produced in this area every year—perhaps from 30 to 50 per cent some seasons—and these breed in the grain fields; but at wheat harvest, instead of migrating to the corn, as is done elsewhere, they go by preference to the timothy meadows. In western New York, where both the long and short winged forms occur, Mr. Van Duzee wrote that he had never found an individual of either form in grain fields, but that they both literally swarm in timothy during some years. Doctor Lintner told the writer that in the serious outbreak of this pest in the meadows of New York in 1882 and 1883 about 20 per cent were of the short-winged form. Doctor Perkins has recorded an attack of the chinch bug in a timothy meadow in northern Vermont. Whether or not the short-winged form was the depredator in this last-named locality the writer is unable to say, but, generally speaking, the short-winged form is unknown at any considerable distance from the coast, except in Maine, New York, Ohio, Ontario, and northern Indiana, and but rarely does it occur in either form in the two latter localities.

Just why this short-winged form should occur in such abundance in the three States named is a matter that the writer is at present unable fully to explain; but it does seem that this difference in food habits as

between the two forms and the limited distribution of the short-winged form inland might open the way to a solution of the mystery. The writer believes that the insect is primarily a tropical macropterous species, and that it has followed the coast from South America along the Gulf and Atlantic northward to Cape Breton, and along the Pacific coast to San Francisco and possibly beyond; also that it spread from northern Mexico and Texas northward as far as Winnipeg, subsisting upon the native grasses, and in the meantime spreading also to the eastward to northern Indiana and Ohio.

On the other hand, from the Atlantic coast there has originated a tide of diffusion the trend of which has been westward, the bugs here partaking more of the nature of their seashore ancestors, more or less of them being of the short-winged form, which their less nomadic habit has served to further emphasize. This tide of diffusion has encountered what the western tide did not, at least until much later, namely, the timothy meadows of the Caucasian agriculturist, and, adapting itself to this food plant, has held closely to it, thus avoiding the necessity of seasonal migration. In northeastern Ohio and possibly in northern Indiana and northern Illinois the western tide of diffusion has met the eastbound tide and is perhaps amalgamating with it. (See map, fig. 17, illustrating supposed direction of diffusion of chinch bug.)

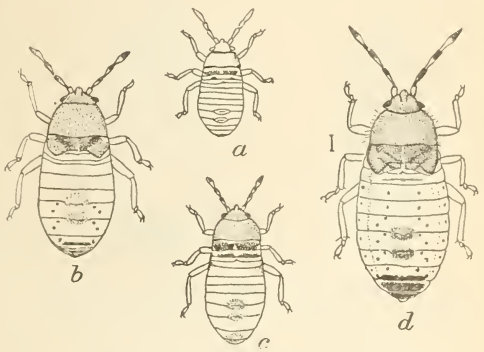


FIG. 18.—*Blissus doriæ*: *a*, first nymph; *c*, second; *b*, third; *d*, fourth. (From illustrations prepared in the Bureau of Entomology.)

Although not at all conclusive evidence, it might be added that the single specimen taken at Winnipeg by Doctor Fletcher was of the macropterous form, while the single example taken by Mr. Van Duzee at Muskoka, Canada, was of the brachypterous form; and this, with the fact that the specimens from the island of Grenada were of the former and the Florida coast specimens of the latter exclusively, shows that latitude and climate have no effect.

HABITS OF THE EUROPEAN SPECIES, BLISSUS DORÆ FERR.

Prompted apparently by a review of one of the writer's papers read before the eighth annual meeting of the Association of Economic Entomologists at Buffalo in 1896, Prof. Karl Sajö, formerly of the Kg. Ung. Staatliche Entomologische Versuchsstation, at Budapest, published a short paper on "*Unser Blissus doriæ*,"[a] which is so full of

[a] Illustr. Wachenschrift für Entomologie, Vol. II, pp. 449–451, July 18, 1897.

interest that the writer has reproduced it here, together with figures of the larval, pupal, and adult stages of the insect (figs. 18 and 19).

Professor Sajö writes as follows:

In the article on the eighth annual meeting of the Association of Economic Entomologists (No. 26, pp. 401–403, Illustr. Wochenschrift für Entomologie) the very instructive observations of Mr. Webster on the "chinch bug" (*Blissus leucopterus*) in the State of Ohio were discussed.

In view of this communication I will give more in detail that which I have observed concerning our European species of this genus, namely *Blissus doriæ* Ferr.

Like the North American larger species, the smaller European one appears in two forms, namely, the wingless and the winged. The first describer of this species, Ferrari, in Genoa, recognized only the wingless form, which with its aborted wings looks very much like Hemipteron-nymphs, and probably by all entomologists who previously saw it was not considered as a sexually developed adult, but only the immature form of some already known species. I discovered the winged form seventeen years ago (1880) in the steppes sand desert, called "Nyires" of the Kis-Szent-Miklos, and described the same.[a]

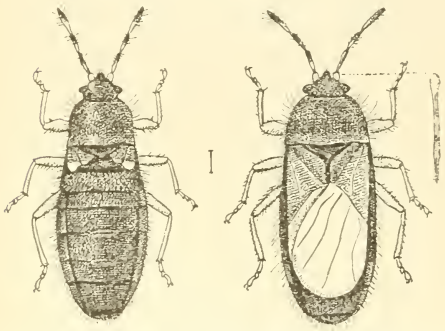


FIG. 19.—*Blissus doriæ:* Wingless form at left; winged form at right. (From illustration prepared in the Bureau of Entomology.)

I at that time made known the characters of the immature forms, which can not be confused with the individuals which have reached complete sexual development, in that the immature individuals are vermilion red while adult individuals are dark brown. It is interesting that the relationship between the winged (macropterous) and the wingless (brachypterous) individuals of the American and European species is very different. For while in America those individuals which reach maturity are almost always winged, with us in Europe they are in general only short-winged, and individuals capable of flight are not observed; and the fully developed macropterous individuals were not thus far, according to my knowledge, found in any other place than in the central Hungarian sand dunes already named, and here they occurred only on a single little portion which only measured a few paces in diameter. It was a "Dunenhugel" (sandy hill) covered with high, scattered poplars, whose fallen, dried foliage sparsely covered the ground.

Here lived the colonies of *Blissus doriæ* on the bases of the bushy, growing grass, almost under the surface of the ground, and well concealed. The habits of the European species are also in the main similar to those of its American relative, since the latter also lives only on grasses, and during its development also lives very close to the surface of the ground.

It is extremely remarkable that, even though *B. doriæ* is very widely distrib-

[a] K. Sajö: "Die bisher unbekannte makroptere Form von *Blissus doriæ* Ferr." Entomolog. Nachrichten, 1880, p. 235.

uted here, and is met with not only on the "Flugsande" (sand drifts), but also in the hilly regions (e. g., on the southern exposure of the hill which stands between Duka and Szod, in the midst of bluffs or rolling hills), the winged specimens were to be found only on the very small "Blissus Island" under the poplars. But here also they were found but rarely, and only then when the transformation from the pupa to adult stage was in full force. When there were no more pupæ to be found, then also the search for long-winged individuals was in vain.

This appearance I explain in this way: That the winged examples, as soon as they were able to fly, quickly flew away and disappeared in order that they might serve as progenitors for new colonies.

But the place of discovery has since been transformed into an immense vineyard by the Government, whereby grass, poplars, and also *B. doriæ* had to disappear from thence. For four years I have, though seeking with the greatest diligence, been unable to get track of the winged specimens anywhere in this region, even though I know of a number of colonies of this species upon my own premises. While formerly I captured a few specimens each year and gave them partly to museums and partly to entomologists, I scarcely hope to attain such interesting finds in the future.

The difference just mentioned between those individuals capable of flight and those not capable of flight in our species and also in the transatlantic species can hardly be accidental, but may be sought for in the influences of environment.

Next there crowds to the front the fact that in North America *B. leucopterus* is continually subjected to the attack of its deadly fungus parasite to a high degree, and its colonies die out as soon as rainy, moist atmosphere prevails. Consequently, the Blissus species living there must always hunt new habitats and be wandering continually to far distant localities. For this wings are of course necessary, and only by means of these is the species enabled to sustain itself at such a high grade of importance that it can, now here, now there, become a veritable plague to agriculture.

With our European species it seems, on the contrary, in regard to many points to be otherwise; for, while her habits in the main are similar to those of her sister across the sea, yet there are found many important differences in their environment.

Blissus doriæ never congregates in such close masses as we read of in the American reports. It forms only insect islands, and even individual families seem to scatter out to some distance. In the steppes, moreover, the growth of grass is not matted, but stands in isolated bunches on the partially bare ground, the bunches being not infrequently separated by several paces.

Our species will not go into cultivated fields. I have never found even a single specimen among forage plants that have been sown, and already this condition is one of the reasons why the European species does not cluster together in such uninterrupted masses.

If, then, this is true the attacks of entomogenous fungi will hardly be able to create such havoc in *B. doriæ* as it does among *B. leucopterus* in America.

I have also during eighteen years never observed a wholesale dying off in the localities of occurrence known to me. The fungus *S. globuliferum* has perhaps never attacked it, and even though the European form were susceptible to similar pestilences, yet it is always hardly to be doubted that the fungus in the European homes of *B. doriæ* would not find favorable circumstances in that here during the period of development of this species in normal years great drought prevails. Rains lasting for a number of days, with continued moist and warm atmosphere, belong, with us, among the rarities, especially during

the summer, and it is the young stages that are especially sensitive to the fungus attack, as has proven to be the case in America.

Among insects there may possibly be found Blissus enemies, even though the extremely penetrating odor of this bug, which is identical with that of the one living in beds in houses, may serve as a protection.

Taking all of this together, we observe that our European species is in less danger than the American, and that it is not subjected to catastrophes of total destruction, so far as has yet been observable in the stationary localities of occurrence in the open field, for I have never yet observed a sudden disappearance from the localities known to me. It is not necessary, therefore, for it to be continually hunting up new fields in which to thrive, and there was no apparent reason which in the struggle for existence would have given preponderance to the long-winged form; and so in time, in the generation of our species, which originally, perhaps, was full winged, the winged form became less and less numerous, until to-day we see almost entirely brachypterous individuals in the adult stage, exactly the same as in the bedbug, *Acanthia lectularia*, with this difference, that among the swarming masses of the latter nowadays not a single example with fully developed wings can be found, fortunately for us.

It is evident that the long-winged tendency in *B. doriæ* is disappearing, and the time may come when one will be unable to find any long-winged specimens. The designated dangers, on the contrary, against which the chinch bug must fight in North America require very strong migratory powers, and, consequently, well-developed wings, through which this especially significant difference between *B. doriæ* and *B. leucopterus* has been brought about.

As to the question whether or not our species shall be considered injurious, I can answer that it in no wise belongs to the entirely indifferent insects, but, on the contrary, contributes to the complete drying up of the rather sparse grasses of our steppe meadows during the summer. But since it has not thus far housed in the cultivated fields, it can not be placed upon the black list of serious depredators. Whether, moreover, in the future, when in consequence of the continued destruction of its herding meadows, its original food plants disappear more and more, *B. doriæ* may become, like so many other insect species, a depredator through necessity can only be conjectured. We have in this regard already recorded entirely too many remarkable transformations in the menu of other species to disregard entirely the possibility of a similar transformation in the life habits of our *B. doriæ*.

I wish also at this time to state, for the benefit of our many readers who may not be familiar with it, that in the dimorphic bugs, especially those in which the macropterous and brachypterous forms are found simultaneously, the former possess a much stronger and broader thorax than the latter. As a result of this difference in their physical structure, one is, when comparing them for the first time, easily inclined to designate them as two distinct species.

In addition to this, there is in Blissus the strikingly beautiful coloration of the long-winged specimens, whose clavus and corium are light ocher-yellow, and the unusually large membrane, which is about twice as large as corium and clavus together and of an entirely milk-white color, making the long-winged individuals very prepossessing. The individuals with rudimentary wings, on the contrary, are of an obscure chocolate-brown. The larvæ are, as has already been stated, of a bright vermilion-red color, marked with black.[a]

With the foregoing, relative to the habits of an allied species of Blissus, it seems to the writer that we can the better understand how,

[a] Translated from the German by Mr. C. W. Mally.

under one set of conditions, all traces of a short-winged form might entirely disappear, while with another set of conditions this tendency might not only be perpetuated, but greatly emphasized. The two species, *B. leucopterus* and *B. doria*, are fully illustrated in all stages of development, as well as both macropterous and brachypterous forms. (See figs. on pp. 21, 22, 23, 83, 84.) For specimens of the latter species, *B. doria*, we are indebted to Professor Sajö.

PREVIOUS IDEAS ON THE DIFFUSION OF THE CHINCH BUG.

Formerly it was supposed that the chinch bug was a native of the Atlantic coast States, and that it made its way westward with the advance of civilization and the consequent progress of wheat growing. This theory was based upon the fact that the original description was drawn up from a specimen from the eastern shore of Virginia, collected by Mr. Say himself,[a] and, as before stated, the earliest destruction on record caused by this insect occurred in North Carolina, and it also committed great depredations in Virginia in 1839. Up to this time it had been supposed that it was a southern species, confined to the country south of latitude 40° north. But about this time chinch bugs appeared in Illinois, at Nauvoo, simultaneously with the settlement of the Mormons at that place, and as many supposed that this sect brought the bugs to the country with them, they were locally termed "Mormon lice."

In his second report, page 284, Doctor Fitch states that Mr. William Patten, of Sandwich, Dekalb County, Ill., informed him that the chinch bug first appeared in that locality in 1850. Mr. Patten, the father of Prof. Simon Patten, of the University of Pennsylvania, and the writer's father, settled in the immediate vicinity of Sandwich, Ill., in 1852. This was ten years after the Pottawattamie chief, Shabbona, and his tribe had migrated to Kansas or Nebraska, the writer does not remember which, but he does recall that it was about this time that the prairie fires ceased to occur over any wide areas, as the prairies were no longer fired annually by the Indians. The whole country was fast being occupied, and he well remembers that the settlers would decide upon a certain date on which they would set fire to the wild grass—in late autumn—so that all could be prepared. It may also be stated that there were very few timothy meadows at that time, as the wild grass afforded an abundance of hay, and not until years after did cultivated grasses come into general use. The writer also knows from personal experience and observation that with the decrease in prairie fires there came an increasing abundance of chinch bugs, which attacked the wheat fields of the farmer. Up to about 1862 these fields were largely of spring wheat, but about that time there

[a] The complete writings of Thomas Say, edited by Le Conte, Vol. I, p.

was a rapid decline in the growing of this grain in northern Illinois. It seems possible that spring wheat might be more liable to attack from chinch bugs than fall wheat, as the former is, at the time when chinch bugs seek out their breeding grounds, more tender and inviting than the latter. Mr. Walter Young, writing from Galesville, Wis., states that his spring wheat was totally destroyed in 1897, though there had been none sown for ten years previous on the premises, and while the chinch bugs did not ordinarily do much injury, just as soon as spring wheat was sown they returned, as it were, and destroyed it.

If spring wheat is so attractive to chinch bugs in spring as this would indicate, might it not be used for baits instead of millet, as is advised further on, in order to draw off the females in spring when seeking localities for oviposition?

This was in a country where there was comparatively little timber, the only forests, if such they could be called, being along the streams of water. The writer is confident that the chinch bug did not suddenly make its appearance in that section, but that with the increase of grain growing and the decrease of prairie fires its effects began to be more and more marked. Since then Prof. S. A. Forbes has secured information of the occurrence of these insects in sufficient numbers to attract attention as early as 1823 in southern Illinois, and within 25 miles of New Harmony, Ind., where Thomas Say resided and did the most of his entomological work.

REASONS FOR THE PRESENT THEORY OF DIFFUSION.

It seems to the writer that in all of this we have good grounds for supposing that the chinch bug occupied the most of the country prior to its occupancy by the white man, and that its first depredations were caused by its own advance coming in contact with the advance of civilization; and the simultaneous cessation of forest and prairie fires, with the displacement of the native grasses by large areas of wheat, so combined that the points of contact were in Illinois in the West and Virginia and North Carolina in the East. Not until within the last twenty-four years has the chinch bug been known to work serious and widespread injury east of the Allegheny Mountains, north of Virginia; and west of these mountains they have done scarcely any damage north and east of a line drawn from Chicago southeast to Cincinnati. Thousands of farmers in Ohio never saw a chinch bug until within the last thirteen years, and there are thousands more in northwestern Ohio, southern Michigan, and northern Indiana that, even yet, would not be able to recognize one were they to see it among their growing grain, or even if in abundance. But in considering this matter the fact must be borne in mind that timothy meadows are not burned over annually as were the

forests and prairies, and the stubble does not die with the harvesting of the crop as in wheat, and therefore annual migrations are not necessary for the bugs in order to preserve life. In a timothy meadow the species may live on and reproduce year after year without ever being obliged to abandon the field. It was the wheat fields of the West that the eastbound macropterous tide of migration found confronting it in Illinois, and the smaller fields of grain and timothy meadows that the combined macropterous and brachypterous forms, more or less maritime and northbound, came in contact with along the Atlantic coast, while at the present time the two tides of migration have met in northeastern Ohio and northern Indiana.

In figure 17 is illustrated the theoretical directions and courses taken by each of these tides of migrations from the tropical regions, and in figure 1 the areas over which the species is now known to occur in Central and North America are indicated.

The writer believes that this same course of migration has been pursued, at least in the West, by the several species of Diabrotica, and especially *D. longicornis* Say, and to a less extent by another species of Hemiptera, *Murgantia histrionica* Hahn and possibly also by *Dynastes tityus* L., while the two latter with others are now working northward along the Atlantic coast. Besides, the westward tide of migration has been followed in all probability by *Pontia rapæ* L., *Phytonomus punctatus* Fab., *Hylastinus obscurus* Marshm., and *Crioceris asparagi* L., all of which have first become destructively abundant west of the Allegheny Mountains in extreme northeastern Ohio. The last four species, having been introduced from Europe, have undoubtedly migrated westward.

With an almost total lack of natural enemies in the United States, and with nearly all of its closest allies belonging in Mexico and the West Indies, it would seem as though we were in possession of additional evidence of the chinch bug's tropical origin. Besides this the name "chinch bug" is of Spanish origin, and this language has never been in common use in North America except in Florida and the country along the Mexican border.

The species certainly prefers the low country to the higher, and is seldom found in any numbers at an altitude of over 2,000 feet. Generally its habitat is 1,000 or lower. The altitude where it was found breeding on Volcan de Chiriqui, in Panama, is 6,000 feet; and of its habitations in Guatemala, San Geronimo, is 3,000 feet; Panzos, 2,000 feet; Champerico, sea level, and Rio Naranjo, about 2,000 feet, while in Colorado it occurs sparingly near Fort Collins at an elevation of 5,500 to 6,000 feet, while Professor Cockerell did not find it at all in the same State at elevations of 7,000 to 8,000 feet. On Mount Washington, in New Hampshire, it has been found only once, and this

time by Doctor Packard, on the summit, which has an elevation of 6,500 feet.[a]

In his own experience, running over something like forty-five years, the writer has never witnessed serious injury by chinch bugs to crops on hilly land. It may be stated, however, that all of his studies of the insect have been carried on in a level country, Ohio being the most uneven and hilly, but even here all of the outbreaks observed were on level areas. In Minnesota, however, Doctor Lugger found that those grain fields which were most seriously injured were located near the edges of woods or on slopes. In some published observations of Professor Osborn, in Iowa, kindly placed at the writer's disposal by Doctor Howard, we find that in 1894 about 90 per cent of the infested fields examined by Professor Osborn were on high ground and about 80 per cent of the fields were hilly and ridges, in most cases the damage being first apparent upon the higher portions of the fields. The exceptions were where the chinch bug had evidently hibernated in wild grass and weeds occurring in the lower places, and these had been very dry for the twelve months preceding the damage of that year. Besides, both the Iowa and Minnesota areas are below 1,000 feet elevation.

The area over which the chinch bug is more especially abundant and destructive comprises such a variety of soils and geological formations that a study of these factors at once shows that neither has any material influence in the distribution of the species, at least in the United States. In its northernmost habitat it would not be at all surprising that it should prefer a sandy, rather than a clay, soil, the former being looser and warmer on or near the surface. (See fig. 10.)

In conclusion, then, on this point it may be stated that if *Blissus leucopterus* originated in the Western Hemisphere it was probably near the Tropics, and it is not impossible that its generic ancestors may have been carried from Europe or Africa by either the north equatorial or the main equatorial Atlantic currents, landing them on the northern shores of South America or on some closely located islands, from which the species has spread coastwise around the Caribbean Sea and the Gulf of Mexico, as previously indicated. In this connection it is interesting to note that specimens from Grenada, collected on the Mount Joy and Caliveny estates by Mr. H. H. Smith in June and September, show that the species here attains a large size and is more variable, both in size and markings, than is commonly found to be the case in the eastern United States.[b]

[a] See paper by the writer on Origin and Diffusion of *Blissus leucopterus* and *Murgantia histrionica*, in Journal of Cincinnati Society of Natural History, Vol. XVIII, February, 1896.

[b] Uhler on Hemiptera-Heteroptera from St. Vincent and Grenada. Proc. Zool. Soc., London, 1894.

INDEX.

Page.

Agonoderus pallipes, enemy of chinch bug 60
Amaranth, food plant of *Nysius angustatus* 32
Anthocoris pseudo-chinche = *Triphleps insidiosus* 60
Ants, enemies of chinch bug 60
Aphides, *Entomophthora aphidis* a fungus enemy 47
Aphodius inquinatus, migrating habit 19
serval, migrating habit 19
Arrhenatherum, food plant of chinch bug 31
Bacillus insectorum, bacterial enemy of chinch bug 57
Bacterial enemies of chinch bug 57, 58
Barley, food plant of chinch bug 31
Barriers, use against chinch bug 65–69, 72
Blackbird, redwing, enemy of chinch bug 59
Blissus, distribution of genus 9
doria, habits 83–87
migratory habit contrasted with that of chinch bug 19
no disinclination to use wings, as with chinch bug 24
leucopterus. (*See also* Chinch bug.)
locality records 9–10
Bluegrass. (See *Poa pratensis*.)
Bobwhite. (See *Colinus virginianus*.)
Botrytis, *Sporotrichum globuliferum* closely allied 53
wrong determination of *Sporotrichum globuliferum* 46
Brachyrhynchus granulatus, mistaken for chinch bug 32–33
Buckwheat, wild. (See *Polygonum dumetorum* or *P. convolvulus*.)
Burning over to destroy chinch bug 61–62, 72
Cabbage bug, harlequin. (See *Murgantia histrionica*.)
Capriola dactylon, food plant of chinch bug 31
Carpocapsa pomonella, change of habits in South Australia 26
Catbird, enemy of chinch bug 59
Cenchrus, only grass not attacked by chinch bug 13
Chinch bug. (See also *Blissus leucopterus*.)
adult, description 22
appearance unique 74–75
bacterial enemies 57, 58
behavior when attacked by *Sporotrichum globuliferum* 55
benefit alleged therefrom 29
bird enemies 58–59
descriptions of stages 21–22
destructiveness largely due to gregarious habits 28–29
development 22–25
diffusion, previous ideas 87
probable course 78–83
reasons for present theory 88–90

Page.
Chinch bug, distribution, geographical ... 9–10
vertical ... 89–90
effect of cold and wet weather ... 18
freezing ... 17–18
egg, description ... 21
period ... 20–21
eggs, number deposited ... 20–21
false. (See *Nysius angustatus*.)
food plants ... 29–31
form from Grenada large and variable ... 90
frog an enemy ... 59
fungous enemies ... 44–58
practical utility ... 58
generations annually ... 25–28
gregarious habit ... 74–75
habits account largely for destructiveness ... 28–29
habits of young ... 22–25
hibernation ... 10–18
influence of precipitation ... 36–43
temperature ... 43–44
insects mistaken therefor ... 31–33
invertebrate enemies ... 60
larval stages, description ... 21–22
long. (See *Ischnodemus falicus*.)
long-winged form and short-winged form ... 22
occurrence and distribution ... 75–77
losses ... 33–36
meteorological influences favoring fungous enemies ... 56–57
migration on foot in search of food ... 24
migrations in spring, summer, and autumn ... 18–20
name of Spanish origin ... 89
natural checks ... 36–44
enemies ... 44–60
origin and diffusion, probable ... 72–90
oviposition ... 20–21
pupa, description ... 22
remedial and preventive measures ... 60–72
short-winged, relation of inland and seacoast forms ... 78
Chrysopa, enemies of chinch bug ... 60
Clover-leaf weevil. (See *Phytonomus punctatus*.)
Coal tar, use in barriers against chinch bug ... 65–68
Codling moth. (See *Carpocapsa pomonella*.)
Colinus virginianus, enemy of chinch bug ... 58–59
Conotrachelus nenuphar, migrating habit ... 19
Corimelana pulicaria, mistaken for chinch bug ... 32
Corn, broom, food plant of chinch bug ... 31
chicken, food plant of chinch bug ... 31
food plant of chinch bug ... 30
Cow blackbirds, decrease held responsible for increase of chinch bugs ... 13
Crab grass, occurrence of half-grown chinch bugs in fall ... 10
Crioceris asparagi, course of diffusion ... 89

Page.
Cymodema tabida, mistaken for chinch bug 32
Decoy plats of grains and grasses, in combating chinch bug 62, 72
Diabrotica, course of diffusion 89
longicornis 76
course of diffusion 89
Dimorphism, in *Blissus doria* 84
chinch bug 22, 75–77
Dispersal of insects, effected by storms 19, 20
Distribution, geographical, of chinch bug 9–10
vertical, of chinch bug 89–90
Drought necessitates watchfulness against chinch bug 63–64
Dynastes tityus, course of diffusion 89
Eciton hamatum, enemy of chinch bug 25
Empusa aphidis = *Entomophthora aphidis* 47
Entomophthora aphidis, fungous enemy of aphides 47
chinch bug 44, 47
sphærosperma, fungous enemy of *Phytonomus punctatus* 55
Epicauta pennsylvanica, attacked by *Sporotrichum globuliferum* 53
Fires, prairie, relation to numbers of chinch bugs 87–89
Flooding, to destroy chinch bug 69
Flower bug, insidious. (See *Triphleps insidiosus*.)
Freezing, effect on chinch bug 17–18
Frog, enemy of chinch bug 59
Fungous enemies of chinch bug 44–58
determination 46–47
field and laboratory experiments in Indiana 47–50
first field applications 51
meteorological influences favoring development 56–57
practical utility 58
work of Professor Snow in Kansas 51–53
Geocoris borealis, mistaken for chinch bug 32
bullatus, mistaken for chinch bug 32
fuliginosus, mistaken for chinch bug 32
limbatus, mistaken for chinch bug 32
Grain, all kinds, food plants of chinch bug 30
Grass, Bermuda. (See *Capriola dactylon*.)
blue. (See *Poa pratensis*.)
bottle. (See *Lxophorus viridis*.)
crab. (See *Syntherisma sanguinalis*.)
meadow foxtail. (See *Lxophorus glaucus*.)
oat. (See Arrhenatherum.)
panic. (See *Panicum crus-galli*.)
Grasses, all but Cenchrus attacked by chinch bug 13
"Hair snake." (See Mermis.)
Herd's grass. (See Timothy.)
Hibernation of chinch bug 10–18
Hungarian grass, food plant of chinch bug 29
Hylastinus obscurus, course of diffusion 89
Insects, dispersal effected by storms 19, 20
Ischnodemus falicus, mistaken for chinch bug 32
Ischnorhynchus didymus, mistaken for chinch bug 32

Page.
Lophorus glaucus, food plant of chinch bug ... 29
viridis, food plant of chinch bug ... 31
Juncus, place of hibernation of chinch bugs ... 15
Kerosene emulsion, use against chinch bug ... 64–65, 72
use against chinch bug ... 64–65
"Killdees," observed feeding on chinch bugs ... 13
Lace-wing flies. (*See* Chrysopa.)
Lachnosterna, attacked by *Sporotrichum globuliferum* ... 53
Lady-beetles, enemies of chinch bug ... 60
Lark, horned, enemy of chinch bug ... 59
"Larks," observed feeding on chinch bugs ... 13
Leaf-bug, ash-gray. (See *Piesma cinerea*.)
Liggrocoris sylvestris, mistaken for chinch bug ... 32
Losses from chinch bug ... 33–36
Martins, decrease held responsible for increase of chinch bugs ... 13
Meadowlark, enemy of chinch bug ... 59
Meadows, difficulty of combating chinch bug therein ... 62–63
Megilla maculata attacked by *Sporotrichum globuliferum* ... 53
Mermis, parasite of chinch bug ... 60
Meterological influences favoring fungous enemies of chinch bug ... 56–57
Migrations of chinch bug ... 18–20
pedestrian ... 24–28
Millet, food plant of chinch bug ... 29
Milyas cinctus, enemy of chinch bug ... 60
Monocrepidius, attacked by *Sporotrichum globuliferum* ... 53
"Mormon lice," early local name for chinch bugs ... 87
Murgantia histrionica, course of diffusion ... 89
not attacked by *Sporotrichum globuliferum* ... 53
Naupactus xanthographus, attacked by *Sporotrichum globuliferum* ... 53
Negro bug, flea-like. (See *Corimelaena pulicaria*.)
Nysius angustatus, mistaken for chinch bug ... 31–32
Oats, food plant of chinch bug ... 31
Oviposition of chinch bug ... 20–21
Panicum crus-galli, food plant of chinch bug ... 29
Parandra brunnea, attacked by *Sporotrichum globuliferum* ... 53
"Partridges," decimation held responsible for increase of chinch bugs ... 13
Pasturing, remedy for chinch bug ... 62
Peliopelta abbreviata, mistaken for chinch bug ... 32
Phleum pratense. (*See* Timothy.)
Phytonomus punctatus, behavior when attacked by *Entomophthora sphærosperma* ... 55
course of diffusion ... 89
Piesma cinerea, mistaken for chinch bug ... 32
Plowing furrows, barriers against chinch bug ... 69, 72
to destroy chinch bug ... 63, 72
Plum curculio. (See *Conotrachelus nenuphar*.)
Poa pratensis, food plant of chinch bug ... 31
Polygonum dumetorum or *P. convolvulus*, food plant of chinch bug ... 31
Pontia rapæ, course of diffusion ... 89
Prairie chicken, enemy of chinch bug ... 13, 59
Precipitation, influence on chinch bug ... 36–43
Preventive measures against chinch bug, difficulty in practice ... 69–71

Page.
Purslane, food plant of *Nysius augustatus* 32
Quail. (See *Colinus virginianus*.)
Rain. (*See* Precipitation.)
Rice, food plant of chinch bug 31
Rushes. (*See* Juncus.)
Rye, food plant of chinch bug 31
Salton Basin, occurrence of chinch bug 29
Sand oats. (See *Uniola paniculata*.)
Setaria glauca. (See *Lxophorus glaucus*.)
Sorghum, food plant of chinch bug 31
"Sparrows, bank," decrease held responsible for increase of chinch bugs 60
Spider webs, occurrence of chinch bugs 60
Sporotrichum globuliferum, first artificial cultivations 54
insects attacked 53
parasitic on chinch bug 44, 46, 47, 53
results of field applications in Ohio 54–56
use against chinch bugs 64, 72
Storms, influence in dispersal of insects 19, 20
Swallow, tree, enemy of chinch bug 59
Syntherisma sanguinalis, food plant of chinch bug 31
Temperature, influence on chinch bug 43–44
Thrush, brown, enemy of chinch bug 59
Timothy, food plant of chinch bug 23, 30, 31
Trap crops (*See* Decoy plats.)
Trapezonotus nebulosus, mistaken for chinch bug 32
Triphleps insidiosus, enemy of chinch bug 60
mistaken for chinch bug 32
Uniola paniculata, abnormal habit of chinch bug thereon 23, 76
Wheat, food plant of chinch bug 31
Wren, house, enemy of chinch bug 59

○

5/16